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INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

XIIth SESSION (CAIRO, 1933).

QUESTION VI:

All-metal rolling stock : carriages and wagons. Use of light metals and alloys. Use of autogenous welding.

REPORT No. 3.

(Germany, Bulgaria, Denmark, Finland, Norway; Netherlands and Colonies; Rumania, Sweden, Czechoslovakia and Turkey),

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The following report deals with the present position in regard to the construction of all-metal carriages and wagons in Germany, Bulgaria, Denmark, Finland, Norway, Holland and the Dutch Colonies, Rumania, Sweden, Czechoslovakia and Turkey. An all-metal vehicle is defined to be one in which the underframe, the body framing, and the exterior panelling are constructed of metal.

The report has been arranged in accordance with the questionnaire drawn up in collaboration with Messrs. GRESLEY and MARIANI, the Reporters on the same subject for other countries. This questionnaire was sent to a total of 41 Railway Administrations in the Countries named above, with a request for the fullest possible information.

A. — CARRIAGES.

I. — General considerations : The advantages of carriages entirely constructed of metal.

At the eleventh session of the International Railway Congress Association held in Madrid in May, 1930, consideration of Question VIII relating to all-metal carriages had already led to the following points being established, amongst others. The construction of all-metal carriages was sufficiently justified by the demand for increased

safety of the travelling public; there was very little difference between the weight of such coaches and those of the older wood construction; a metal construction lent itself in every way to the manufacture of the corresponding parts in large quantities; and metal coaches could provide a standard of passenger comfort at least equal to that afforded by vehicles of wooden construction.

In view of the relatively short time that such vehicles had been in operation, it was not then possible to arrive at any definite conclusions as to whether they would be economical from a maintenance standpoint, but the results so far obtained were such as to encourage further study of this point. There were still a number of investigations to be made, not only as regards the choice of manufacturing processes and of materials, but also in respect of the details of the interior equipment.

Having regard to the experiments carried out by several railways for reducing weight by the use of more or less special steels of greater strength and of light alloys, the Congress recommended that further study of the employment of such metals should be made.

Out of the 41 Railways, 10 have responded to the questionnaire by forwarding further information for the preparation of the report; 15 replied that they had no steel coaches, while the remaining 16 had not sent any information up to the time the report was drafted.

The following statements, based on the information submitted, indicate the present position on the various Railways of the Countries in question.

Germany.

The *German State* Railways, in accordance with the principle decided upon a considerable time ago, have continued to extend the use of all-metall construction in the building of new passenger coaches. Their experience with some 10 000 steel carriages that had been constructed by the beginning of 1930, and with the additional all-metal vehicles that had been built since that time, has been so favourable that a reversion to building passenger coaches of wood construction could only be considered as a retrograde step. Adherence to the policy which they adopted has enabled them to make progress of a particularly important character in recent times, since by the use of autogenous welding and careful adaptation of the details of design they have been able to effect considerable reduction in weight without employing expensive light metals, and light alloys. Using steel alone the weight of a D (express) train coach has been reduced from about 47.0 t. to 37.5 t. (46.3 to 36.9 Engl. tons), equivalent to approximately 20 %. This has been achieved without alterations to the manner in which the space is divided, or to the dimensions which affect the comfort of passengers. Moreover, the rigidity and strength of the coaches to resist collision have not been diminished.

In another type of welded coach the artificial wood « Histoxyl » referred to in my report to the Madrid Congress has been used to effect a further reduction in weight down to 36.5 t. (35.9 Engl. tons), which represents a total saving of 22.3 %. In 3rd class corridor express coaches of these types having separate compartments and accommodating 80 passengers, the weight per seat has fallen from 587 to 469 and 456 kgr. (1 294 to 1034 and 1 005 lb.).

In the case of trailers for motor coach trains which do not have to withstand the longitudinal stresses present in long trains, it has been possible by the use of welding, and employing high-quality steel, together with a specially light design of the details and of the wooden interior structure, to produce a vehicle weighing only 18 t. (17.7 Engl. tons), including the two bogies; this carriage is about 19 m. (62 ft. 4 in.) long and as

it seats 90 passengers, the weight per passenger is only 200 kgr. (440 lb.). Tests carried out with a loading of 7.5 t. (7.4 Engl. tons), and at speeds up to more than 130 km. (81 miles) per hour have shown that the running qualities are entirely satisfactory.

An equally low weight per seat has been obtained in 4-wheeled trailer cars of similar design.

The figures quoted above prove that it is possible to go beyond the conclusion arrived at in Madrid that the weight of a carriage of all-metal construction would not exceed that of one made of wood, since they show that a considerable reduction in weight can be effected in steel carriages of railway type embodying the standard of comfort usual in railway passenger stock; moreover, groups of these vehicles are to be constructed and put into normal service. It is unnecessary to enlarge here upon the advantages which these vehicles must offer for more economical and rapid operating, and when subjected to the hardest service in deliberate competition with road vehicles.

Finland.

The *Finnish State* Railways report that they are not contemplating the construction of all-metal vehicles. The management consider that the cost of this type of construction is considerably higher than that of vehicles built of wood. With the exception of the mouldings, window frames, and fittings of the doors and seats, the whole of the body is made from home-grown timber. The management is of the opinion that the weight and probably the consumption of steam for heating purposes would be greater than for vehicles constructed of wood.

Norway.

The *Norwegian State* Railways also have not yet built any passenger coaches of the all-metal type, but they are considering the building at some future time of all-metal carriages for international traffic. More detailed reasons for this partial adoption of metal construction were not given.

Holland and her Colonies.

The *Netherlands* Railways propose to adopt all-metall construction for all new carriages for the home country. The reasons given for this are firstly that the reduced risk of accidents is in the interest of passengers, and secondly the advantage to the railways of the diminished cost of maintenance.

The Dutch Indies State Railways and Tramways do not at present contemplate adopting all-metal construction for all the carriages operating on the suburban lines. The introduction of such vehicles depends upon the experience obtained with the all-metal vehicles that have already been ordered in Holland for service on the Company's main lines. The carriages are cheaper than any other type, although this may be due to the general economic conditions that now prevail.

All-metal carriages have been running for about ten years on one urban express line and have proved thoroughly satisfactory. As these carriages are equipped with powerful fans, and are operated at high speeds, the difficulty of a high temperature — which is the main objection to the use of metal vehicles in the tropics — has been hardly noticeable.

Rumania.

The *Rumanian* Railways intend to adopt all-metal construction for all new carriages. The reasons given are greater safety for passengers and the higher degree of resistance to wear and tear. Metal construction is more suitable than wood construction in a climate subject to the considerable temperature variations which occur in this country.

Sweden.

The *Swedish State* Railways intend to use metal construction only for bogie carriages, and wood will still be used for the floors and inside panelling. It is their opinion that the metal form of construction increases the strength of the vehicles and thus adds to the safety of passengers.

The *Uppsala-Norrland* Railway associates itself with the views expressed by the Swedish State Railways.

The *Kalmar-Nya* Railway has just acquired an all-metal vehicle, and has not yet been able to obtain any real experience with it.

II. — Progress in all-metal construction in relation to new series of vehicles and the increase in number of vehicles.

The following information has been reported by the 6 countries which have adopted all-metal construction for passenger vehicles.

Germany.

The total number of coaches and luggage vans for passenger trains and rail motor vehicles is approximately 76 000; the growth in the number of all-metal vehicles is shown by the following table.

Express-train stock :

	Number at 1 Jan. 1930.	Number at 1 Jan. 1932.	Increase.
A 4 ü	34	34	—
AB 4 ü	300	368	68
ABC 4 ü	70	120	50
B 4 ü	38	38	—
C 4 ü	481	517	36
Pw 4 ü	207	430	223
Pw Post 4 ü	20	20	—
Total :	1 150	1 527	377

Fast train and ordinary passenger train stock :

B 4 i	4	289	285
BC 4 i.	24	381	357
C 4 i	41	1 236	1 195
B i	1 697	1 702	5
BC i	974	979	5
C i	2 883	2 888	5
B	10	10	—
BC	40	10	—
Pw 4 i	—	102	102
Pw i	744	928	184
Total :	7 570	9 708	2 138

Rail motor vehicles and trailer coaches :

e a T (Double carriages)	18	18	—
v T	56	57	1
e l T (52 Jakob carriages)	86	104	18
e l (trailers)	18	33	15
e s (trailers)	682	769	87
e s T	676	744	68
Total :	1 536	1 725	189
Together :	10 256	12 960	2 704

It will be seen that the number of all-metal carriages added amounts to some 26 % of the number of such vehicles in service at the 1 January, 1930, while the proportion of such vehicles in relation to the total quantity of rolling stock has increased from about 13 % to 17 %.

The fact that there was no increase, or a comparatively small one in the number of 4-wheeled vehicles of the *Bi, BCi, Ci, B, BC* and *Pwi* classes is accounted for by the *German State* Railways having adopted bogie vehicles even for ordinary passenger trains. 4-wheeled carriages will be built in future only for service on routes where low speeds are the rule and the traffic conditions are of a simple character.

The additional vehicles that were under construction at the 1 January 1932, were as follows :

ABC 4 ü	20	vehicles.
C 4 ü	28	»
Pw 4 ü	5	»
C 4 i.	32	»
Pw 4 i	203	»
Pw i	20	»
v T	57	»
e l T	18	»
e l (trailers)	12	»
e s T	51	»
e s (trailers)	51	»
Total	497	vehicles.

New types of vehicles constructed entirely of metal, which have been developed and in some cases completed since the preparation of the report for the Madrid Session are :

1. New types of all-steel carriages for through express trains, fast trains and ordinary passenger trains operating on main lines. In these welding has been used for joining the separate members of the under frames, body framing and bogies.

2. New types of carriages for ordinary passenger trains on branch lines of standard and narrow gauge, in which a similar method of construction has to some extent been used.

3. Light rail motor coaches and trailers for main and branch lines, built of steel.

4. New light vehicles for the Berlin Metropolitan Railway in which light metal and light alloys are used.

In common with all the new vehicles of the German State Railways built during recent years, the four types specified above are of the corridor type. Moreover, as hitherto, the body framing and underframes of all these vehicles are built integrally so that the former contributes to resisting the tractive, bending and impact stresses.

Under (1) above : *New types of steel carriages for through express trains, fast trains, and ordinary passenger trains.*

Since the Madrid Session the *German State* Railways have continued the development of the steel vehicles that it then had in service.

Whilst riveting continues to be used for the new steel vehicles now under construction, 7 carriages for through express trains, and six 8-wheeled carriages for ordinary express trains, have been put in hand as an experiment in which the fullest possible use is to be made of the latest methods of uniting the steel parts by welding and of utilising high-grade steel. The riveted vehicles enabled noteworthy reductions in weight to be made per passenger, per unit of floor surface, and per unit of overall length, as compared with the older carriages of wood construction, but with the experimental carriages it is the aim to achieve further considerable reduction of weight for carriages of the same dimensions and strength. Success in this direction is not unlikely in view of the satisfactory results already obtained with welded bogies, which are the parts that are subjected to the greatest strains in service.

In order that the adoption of welding may be standardised on sound lines as quickly as possible, the particular method of construction of any individual firm of rolling stock manufacturers is being used for only a few of the 13 experimental carriages, and the orders for the vehicles have been distributed amongst 6 makers with the express instruction that each contractor shall carry out the welding in accordance with his own ideas.

The weights of the individual parts

of one of the new riveted express carriages of all-metal construction, having a total length of 21.720 mm. (71 ft. 3 in.) over the buffers are tabulated below :

Underframe, including brake equipment but without brake cylinder	5 800 kgr. (12 790 lb.)
Cylinder for quick-acting brake	700 kgr. (1 540 lb.)
Body frame and external panelling but without inside work	7 100 kgr. (15 650 lb.)
Inside structure including floor, partitions, interior doors, ceiling, windows, seats, lavatory fittings, etc...	13 490 kgr. (29 740 lb.)
Draw and buffing gear	1 390 kgr. (3 065 lb.)
Bogies without wheels, but including brake gear	11 000 kgr. (24 250 lb.)
Wheels and axles	4 600 kgr. (10 140 lb.)
Steam heating	1 130 kgr. (2 490 lb.)
Lighting equipment with battery	1 250 kgr. (2 760 lb.)
Total :	47 000 kgr. (103 000 lb.) approx.

These figures show that the parts in which economy in weight can be mainly obtained by welding, especially the underframe and body, amount to only 12.9 t. or 27.5 % of the total weight.

Even though the most careful attention is given to reducing the weights of these parts, the total weight of the carriage would only be reduced by an unappreciable amount unless considerable reductions can also be effected in the other parts of the vehicle.

Therefore, when ordering the 13 welded bogie carriages, the various contractors were instructed to redesign the other portions of the carriages carefully with the object of reducing their weights by the greatest possible amount.

This should result in some of the vehicles having a lighter form of interior, for which a wooden type of construction is, in general, being retained. Here again, the builders are permitted to make proposals in order that the most practical design may be arrived at as speedily as possible for subsequent adoption as the standard method of construction.

In order that a reliable comparison may be made of the economies in weight effected by welding and by the special designs of the interior work, the principle has been laid down that no variations may be made in the length, height or width of the carriages or the arrangement of the partitions. It was also stipulated that whatever reduction in weight might be made, the strength to resist impact must be at least as great as that of the earlier riveted design, and that the interior must be constructed and finished in a manner as pleasing and comfortable for passengers as is found in the newest vehicles that had previously been built.

The use of aluminium or aluminium alloys in these carriages has been ruled out so that the first cost and maintenance charges may not be higher than those for earlier vehicles.

Light forms of construction that will be allowed for other parts of the carriages are :

The window frames will be built up of drawn hollow brass sections as previously used for other passenger coaches of standard construction. In place of the ordinary cast-iron brackets for supporting the luggage racks, that have been fitted up to the present, much lighter brackets of special cast metal will be used. The earlier cast window-brackets for the collapsible tables will be replaced by brackets of pressed sheet metal

having stiffening ribs welded on to them. These refinements will result in a total saving of about 250 kgr. (550 lb.).

Whereas the steam heating in the earlier carriages constructed of wood, and also in the later riveted all-metal carriages, was carried out with pipes having a 3.5-mm. (0.138 inch) thickness of wall, in the welded carriages the material of the pipes will be only 1.5 mm. (0.059 inch) thick. The steel used for the pipes contains 0.5 % of copper to render them sufficiently resistant to rusting. The total weight of the heating equipment will be still further lowered by a lighter design of the steam regulating valve, and other parts, which will save about 550 kgr. (1 210 lb.) or nearly half the weight of the older design.

Additional saving of weight, amounting to 300 kgr. (660 lb.) will be obtained by the use of a lighting battery of the alkali type.

Efforts with also be made to effect a further saving in weight in the case of some of the welded carriages by the incorporation of a new type of brake gear. Carriages are being built with subdivided brakes, that is to say, the existing type of brake gear is used, but it has been moved from the underframe on to the bogies. Although the use of several brake cylinders does not in itself reduce the weight of the brake equipment very much, nevertheless the removal of brake details from the body framing and the consequent relieving of the underframing from the considerable braking stresses, permits a lighter construction of the body framing with a corresponding saving of weight. Other of the vehicles are being fitted with drum brakes, and with caliper-type brakes. If these brakes prove satisfactory when the tests are made and can be operated successfully with the present standard brake system, there is a possibility that economies can be effected in the weight of the brakes which will be in the neighbourhood of 50 % of the weight that is now usual for this equipment.

Three of the D (express train) carriages out of the thirteen that have been ordered have already been completed and subjected to trial runs. With the object of checking the calculated weight reductions in the individual wood and steel parts, the following programme was worked to by Messrs. Wegmann, of Cassel, who were responsible for constructing the three vehicles :

a) The first carriage was welded and the steel parts were specially designed to suit this process, but the interior work which was of wood construction was carried out in precisely the same manner as in the riveted steel D-train carriages;

b) The second carriage had an entirely new design of interior constructed of the artificial wood « Histoxyl », whilst all the steel portions were built in accordance with the present practice for the riveted D-train carriages;

c) In the third carriage the artificial wood interior as used for carriage *b*) and the welded steel construction as used for carriage *a*) were combined. There were thus available all the combinations necessary to ascertain the savings in weight due to the particular method of construction used for the wood and the steel portions respectively.

The « Kunze-Knorr » brake system for high-speed trains, as used by the State Railways on their D-train carriages, was fitted to the three carriages in question without any modification, and apart from a certain reduction in the weight of the brake rods no special lightening of the brake equipment was effected.

The weight reductions that had been calculated were checked by weighing. As against a figure of 47 t. (46.3 Engl. tons) for a standard carriage of riveted all-metal construction, the carriage *a*) above weighed only 40.1 t. (39 Engl. tons), so that a saving has been effected in the steel parts which amounts to 6.9 t. (6.8 Engl. tons) or approximately 15 %.

Carriage *b*) above weighs 43.8 t. (43.1 Engl. tons). This shows that 3.2 tons have been saved in respect of the wood portions and the iron fittings of the carriage, or 6.7 %.

Carriage *c*) above in which reductions in weight were made in both directions, weighed 39.1 t. (38.5 Engl. tons), giving a saving of 7.9 t. (7.8 Engl. tons) or approximately 17 %.

The German State Railways are now using the so-called heavy Görlitz III type of bogie with a wheel base of 3 600 mm. (11 ft. 9 3/4 in.) for the new light type

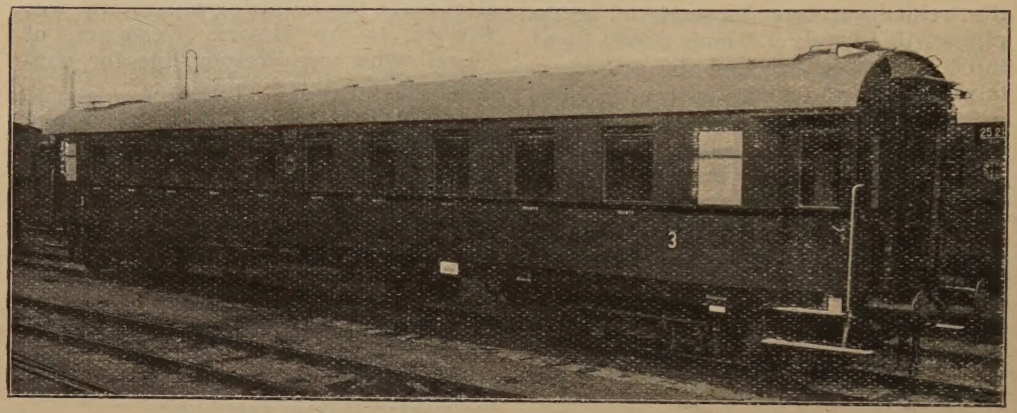


Fig. 1 — Welded all-steel D (express) train carriage, Wegmann & Co., Cassel.

of express and 8-wheeled carriages when the total weight is more than 40 t. (39.4 Engl. tons), and the light Görlitz III bogie with a wheel base of 3 000 mm. (9 ft. 10 1/8 in.) for carriages weighing less than 40 tons. Both types have given equally satisfactory results even on fast runs at the highest speeds yet reached [153 km. (95 miles)]. When the three experimental carriages were ordered, it was decided to specify welded bogies of the heavy pattern, since the details of the welded construction had yet to be worked out and the eventual saving in weight was not then known. Now that reliable data concerning the reduction in weight is available new welded bogies of the « light III » type are being ordered for both the light carriages under *a*) and *c*) above. In spite of the fact that these bogies are designed to withstand the higher stresses imposed by the Kunze-Knorr brakes, their use results in a further reduction of weight amounting to about 2.6 t. (2.56 Engl. tons) per vehicle, and the *a*) carriages will therefore weigh approximately 37.5 t. (36.9 Engl. tons) and the *c*) carriages 36.5 t. (35.9 Engl. tons). Compared with the earlier riveted carriages this shows a reduction of 9.5 t. (9.35 Engl. tons) = 20 % approx., and 10.5 t. (10.3 Engl. tons) = 22 % approx. These new weights indicate therefore that the welded D-train carriages with their enclosed compartments and continuous corridor partitions can be built to be as light as the existing riveted type of 4-axle light passenger carriages without any alteration to the brake system.

If the two other builders, each of whom has in hand 2 D-train carriages of welded type, are successful in designing the same wood and steel parts so that similar weights are arrived at, it follows that the D-train carriage they are building with the new and much lighter design of brake equipment will show a still greater saving of weight. These car-

riages will be completed during the autumn of 1932.

Figure 1 is an exterior view of a finished D-train carriage of welded construction. There is scarcely any difference between this vehicle and one of the existing riveted carriages for the reason that, as stated earlier, the same floor-plan has been adopted with 80 third-class seats as before, and no alteration has been made to the dimensions of the carriage or the separate compartments.

In the same way each of three further manufacturers has been commissioned to build two 8-wheeled light carriages for express and ordinary passenger service. Here again the aim is to obtain the greatest possible reduction in weight of the steel parts by employing welding, and of the parts constructed of wood by introducting new designs. In addition some of the vehicles will also have new brake equipment of lighter type. It will not be possible however to obtain reductions in weight of the same extent as in the case of the D-train carriages; this is

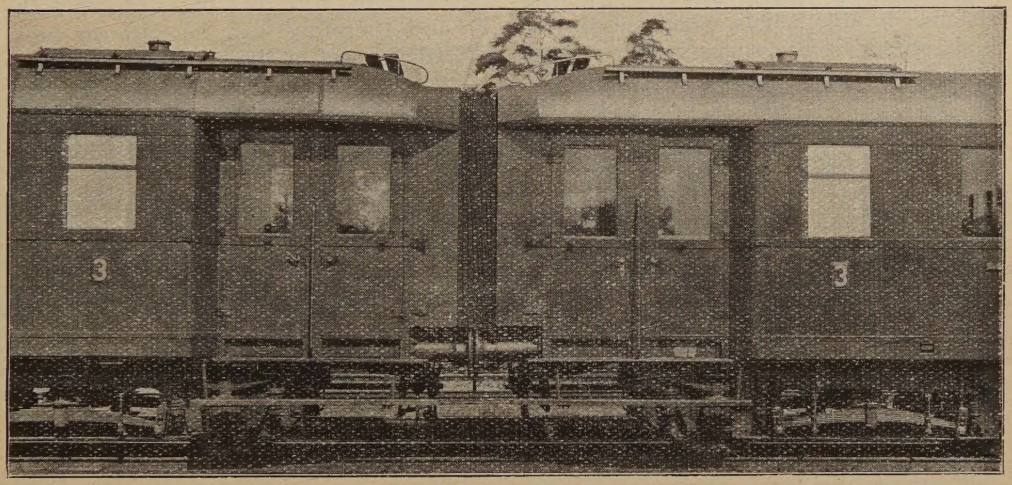


Fig. 2. — Large vestibule connection between carriages.

due, in the first place, to riveted carriages having already been developed in recent years which incorporated high-quality material in the underframe and which had been very carefully designed with a view to lightness, and secondly on account of these carriages having already been fitted with the light type of Görlitz III bogie. Notwithstanding these circumstances very considerable savings in weight are still anticipated, due mainly to the use of welding. These carriages will be completed and tested in the autumn of 1932.

The efforts to reduce in the most thorough manner the weight of the individual coach and therefore of the train are directed towards economy in operating expenses, or attaining higher speeds with the same locomotive output both on the level and on up grades. In addition to the steps taken to diminish running resistance, other measures are being adopted for the purpose of reducing wind resistance at the higher speeds. In carriages of welded construction, for example, the windows are brought as near the outside surface of the vehicle as possible to reduce the depth of the recesses which are particularly liable to be caught by a

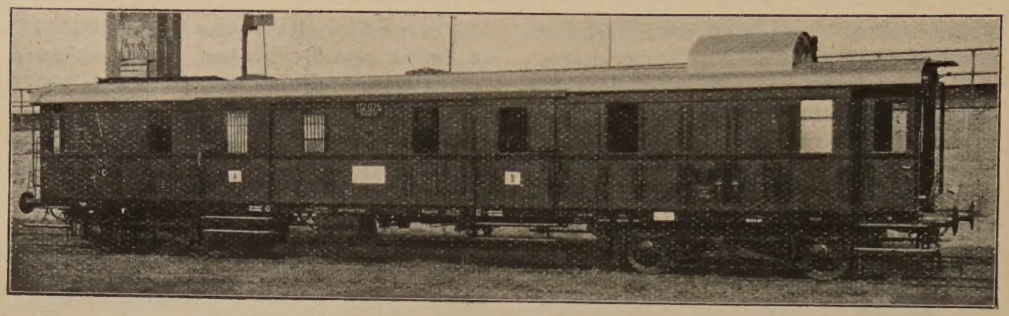


Fig. 3. — Light 8-wheeled luggage van for stopping passenger trains.

side wind. A still greater cause of resistance to side winds when running at high speeds is the space between adjacent carriages. To determine the amount of the resistance due to this cause, the 8-wheeled light corridor coaches were equipped, for test runs at particularly high speeds, with special bellows connection pieces which enclosed the entire end of the vehicle (fig. 2) and made the sides of the train as unbroken as possible.

As the necessity for strict economy only permitted these tests to be carried out with existing carriages, it was not possible to modify the shape of the carriages to the most favourable lines on account of the convex shaping of the ends.

For the test runs with these carriages the ventilators in the roof were removed. Even though these inexpensive modifications are certainly not to be taken as indicating a final design which will give minimum air resistance, the results in conjunction with tests carried out with models in a wind duct should give practical guidance of a valuable kind as to how far the wind resistance can be diminished if similar modifications are eventually embodied in a design of carriage that is perfectly streamlined. Speeds of up to 153 km. (95 miles) per hour have already been attained with carriages that have simply been adapted in this way for research purposes. Throughout these tests the carriages ran smoothly and therefore can be said to have afforded proof of the reliability of bogie passenger stock at very high speeds both in respect of their good running qualities and also of that standard of safety which is so essential for passenger traffic.

Suitable eight-wheeled luggage vans of riveted all-steel construction and light design, have also been built for use with the class of light eight-wheeled passenger coaches for express and ordinary service (fig. 3). In these carriages the roof of the guard's cabin is shaped at the side in such a way as to permit observation even from the locomotive, of the train-end lamps that are carried above the roof on the carriages of the State Railways.

In a further luggage van of the same class that is under construction the guard's cabin superstructure is being built in streamline fashion.

Under (2) above : *new types of carriages for ordinary passenger trains on branch lines.*

As previously mentioned, the *German State* Railways have decided to adopt bogie carriages even for ordinary passenger trains, and to allow four-wheeled stock to be built only for routes operated at low speeds on which the traffic conditions are of a simple character. As the sharp curves met with on branch

lines necessitate the use of carriages having a moderate distance between axles, they have given up the former design with four wheels and 8.50-m. (27 ft.-10 5/8 in.) wheel base, which had already been constructed in all-metal fashion for main line working, and have built somewhat shorter 4-wheeled carriages with nearly the same seating capacity (56 instead of 58) but with a wheel base of only 6.20 m. (20 ft. 4 in.). The increased overhang of the carriages is unimportant, since in any case they do not run at speeds of more than 65 to 70 km. (40.4 to 43.5 miles) per hour. Riveted construction has still been retained for the first of these new carriages (fig. 4). This design has resulted in the reduced weight of 16.5 t. (16.2 Engl. tons) compared with 21.00 t. (20.7 Engl. tons) for the main line carriages of 8.50 m. (27 ft. 10 5/8 in.) wheel base, that is to say a saving of some 21 % for a seating capacity of 56 (instead of 58). Any additional saving in weight is particularly desirable because in Germany many of the branch lines are situated in hilly country. In view of this and of the satisfactory experience obtained meanwhile with the

Fig. 4. — Light 4-wheeled carriage for passenger trains on branch lines.

first welded D-train carriages, the firm engaged in the development of the latter was entrusted with a contract for building additional experimental carriages with the same floor plan and seating capacity but in welded instead of riveted type of construction. The method of construction is being adapted from that employed for the welded 8-wheeled carriages. It is anticipated that these vehicles will show a further saving in weight as compared with the first riveted design and even that the weight will be kept below 15.0 t. (14.76 Engl. tons). This would mean a reduction of about 6.0 t. (5.9 Engl. tons) or 29 % in comparison with the main-line carriages.

Special luggage vans constructed on the same lines have also been ordered for this class of carriages.

In addition to these carriages for standard gauge an 8-wheeled vehicle of all-metal construction has been designed for a gauge of 900-mm. (2 ft. 11 1/2 in.) (fig. 5). It embodies the same type of riveted construction that has been used hitherto for standard-gauge all-metal carriages.

In this case also, the requirement of low first cost has prevented the use of aluminium or alloys of that metal. The weight of the carriage is 11.9 t. (11.8 Engl. tons) and it has accommodation for 30 second class passengers.

Specially light all-metal standard-

Fig. 5. — Carriage for 900-mm. (2 ft. 11 1/2 in.) gauge branch line.

gauge carriages were then built, both with and without a luggage compartment, for use as trailers in conjunction with the heavy motor-coach vehicles that had been built earlier, and in which riveting and welding were both used. These vehicles are intended to run also with goods wagons and ordinary passenger train stock and therefore have a rigid underframe to resist impact stresses; their weight with seating for 48 third-class passengers amounts to about 13.0 t. (12.8 Engl. tons). *Silumin* has been used for the furniture of these carriages such as the brackets for the luggage racks, and door handles, and also for the ventilators in the roof (fig. 6).

Under (3) above : *Light rail motor coaches and trailers for main and branch lines.*

The continuous deterioration in the economic position and the steady falling off of passenger traffic that has proceeded during the last few years, as well as the growing competition from road and air transport have compelled the railways to give greater attention to the building of rail motor vehicles for passenger service. Consideration had to be given to the best means of working the lines more economically, especially those on which there was very little traffic, by devising light and cheap vehicles with low fuel consumption; and as to how improved frequency and rapidity of the services could be made to retrieve passenger traffic that had been transferred to motor buses and other vehicles, or at any rate check further loss of traffic.

Such results can only be achieved by using small units such as are easily rendered available by rail motor coaches. Locomotives with their considerably greater hauling capacity are not at all suitable for attaining the objects in view.

As a first step it was decided to run trains with the maximum frequency on a shuttle service between Francfort-on-Mein and Wiesbaden and three 8-wheeled rail motor coaches and three trailers were ordered in the Spring of 1930. The requirement that a trailer had to be hauled at a speed of 90 km. (56 miles) per hour, necessitated a motor of somewhat considerable power. At that time suitable high-speed Diesel engines were not yet available, but proposals were submitted by the Maybach Company for a 12-cylinder traction-type Diesel engine of 410 H. P. Considerable time was required for the construction and testing

of this unit, and it has only been possible to test the first of the vehicles quite recently (fig. 7).

The trailer coaches were taken from a delivery of new 8-wheeled express vehicles, and to eliminate the loss of time due to the driver changing ends, they were provided with a driving compartment. The motor coaches and trailers are constructed in accordance with the specification in force at that time for riveted all-metal vehicles. The mo-

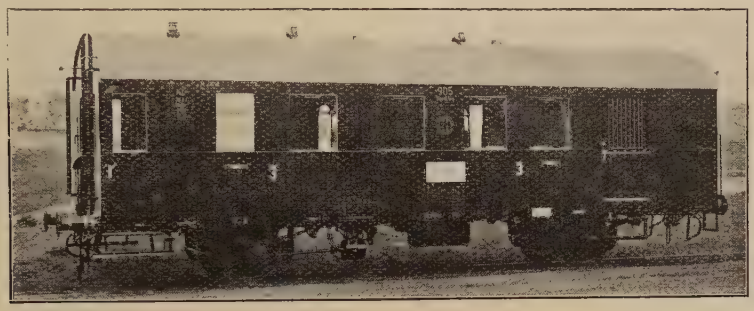


Fig. 6. — Light trailer for heavy motor-coach.

Fig. 7. — 410-H.P. rail motor coach.

tor coaches accommodate 56 third-class and 16 second-class passengers, and weigh 50 t. (49.2 Engl. tons), the trailers seat 84 third-class passengers and weigh 38 t. (37.4 Engl. tons). According to present-day views these weights are too high. Rail motor coaches of limited power not only now have to run on lines with gradients and be capable of starting and stopping quickly in order to give the necessary increase in speed, but must at the same time have sufficient reserve power to permit the attachment of a trailer when the traffic conditions require it. For these reasons it is imperative that the weight of these vehicles should be reduced to the minimum. The use of petrol motors is not favoured on account of the considerable fire risk. Great progress has now been made in the development of Diesel engines suitable for rail motor coaches and this has enabled an advance to be made in designing such vehicles with satisfactory operating characteristics. It is, however, still difficult to effect a

reduction in weight of the power equipment and any saving in this direction has to be sought mainly in the lightening of the carriage structure.

In considering the best means of developing a light form of construction attention is naturally directed to reducing the weight of the structure by the use of light metal or light alloys. It is not possible, however, merely to substitute such materials in existing designs based on the use of steel, as this course would not produce the lightest vehicle that would be strong enough for railway service. The light metals have characteristics which necessitate special and very careful treatment of the constructional design.

The modulus of elasticity of light metals or alloys, varies according to the precise composition, with a maximum value of about 70 000 kgr. per cm^2 (995 600 lb. per sq. inch.), which is only about one third of the corresponding figure for steel. The low modulus of elasticity results in a tensile strength which is also not more than one-third of that of steel, so that if an attempt is made to avoid increasing sectional areas, a balance has to be struck between reducing the length of the members and increasing the moment of inertia by using a favourable shape of cross section. Another point is that steel withstands temporary stresses beyond the elastic limit much better than light metal which has considerably less resistance under continuous stress. This necessitates special care in the use of sheet aluminium for panelling when such panels replace the diagonals of a braced frame, as is generally the case in passenger stock, and have therefore to resist certain forces. Excessive stresses must be carefully avoided since otherwise the light metal will become brittle. In such cases it is necessary to select a greater thickness for the sheets or to stiffen them.

The weakness of light metal to resist distortion and the softness of its surface are particularly objectionable in parts that are subjected to considerable pressure or to wear and tear. These disadvantages can be overcome by increasing the area under compression or interposing some harder material.

Riveting also requires special care. The riveting of light metal being a cold process as opposed to the method used in steel riveting, the powerful forces exerted by the contraction of the hot rivets are entirely absent. Shear forces in light metal riveted construction are therefore resisted chiefly by the cross-section of the rivets and not by the friction between the sheets as in riveted steel work. It follows that with light metal the number of rivets must be increased and their cross-section correspondingly reduced.

Another property of light metals and light metal alloys which proves a great disadvantage is that the strength of these materials decreases very rapidly with increase of temperature, while high-tensile alloys lose their special qualities under heat treatment and parts constructed of this material have to be re-annealed after being worked hot. Then again the resistance to corrosion is low especially in the case of the high-grade alloys. As pure aluminium, though lacking in strength, is the best material to resist corrosion, it has become the practice to protect sheets of mechanically stronger alloys by rolling pure aluminium on to them; this process adds still further to the cost of these materials.

Hence the possibilities of economising weight offered by the light metals and alloys as compared with steel is largely nullified in just those cases where the use of the very expensive light material is desired for structural members, on account of the unavoidable increase of cross section.

The adaptation of the various parts to carry the stresses that occur is pos-

sible not only with light materials, but also in steel construction by using special profiles and constructing the members out of flanged sheet metal of suitable form and thickness; moreover, weight can be reduced by using special steel of high tensile strength, and the steel can be made to resist corrosion by the addition of copper.

For the reasons outlined above the State Railways have hitherto only allowed the use of light materials on a considerable scale in the suburban train described in detail later, and they will determine from experience with this rolling stock the extent to which the use of expensive light materials is possible in meeting the severe mechanical stresses of passenger stock; the economy of the design from the maintenance point of view will also be studied.

On the other hand the light type of rail motor coaches and trailers that have already been completed and for which further orders have been placed are of steel construction. This decision was based on the conviction that the use of the considerably cheaper high-quality steel would result in approximately the the same weight for at least equal strength, greater durability and materially lower cost.

For branch lines, four-wheeled rail motor coaches have been built for a speed of 65 km. (40.4 miles) per hour, with 100 and 120-H. P. engines. The vehicle weighs 12.0 to 13.5 t. (11.8 to 13.3 Engl. tons) empty, and in working order an additional 0.5 ton. The older rail motor coaches of similar construction but with engines of smaller horse power weighed 18 to 20 t. (17.7 to 19.7 Engl. tons). The new coaches have approximately 8 H. P. per ton of tare weight as against 3.75 H. P. in the older vehicles. The weight per square foot of floor surface has fallen by about 40 % while the engine power per ton of tare weight has increased by some 113 %. Due to their ability to start rapidly and stop quickly the new carriages have enabled the journey speed to be raised considerably; they are intended for service on branch lines with numerous unattended level crossings and in hilly districts.

The body framing and underframe are of high-grade steel and welding is used extensively in place of riveting (fig. 8).

The trailer cars of similar construction weigh only 9 t. (8.85 Engl. tons) for a seating capacity of 44. Lavatory accommodation is provided and large end platforms for standing passengers (fig. 9).

The interior of the motor coaches and trailers is arranged as a large compartment and decorated in a simple but adequate manner. No second class accommodation is provided. Side buffers and a simple screw coupling are fitted, without an emergency coupling. The buffers and couplings are of specially light construction, as these carriages are not intended to be made up into trains or to run with standard stock; the buffers and couplings can be easily removed in the event of it proving desirable to run the motor coaches by themselves on certain routes. A large luggage compartment is provided in the motor coaches.

Special light eight-wheeled rail motor coaches and trailers are being built for main lines and branch line service, constructed according to the same principles. The engine power of the motor coaches is 175 H. P., and the weight of the empty vehicle 29 t. (28.5 Engl. tons) (fig. 10).

The trailers for these motor coaches weigh only 18 t. (17.7 Engl. tons), and have seats for 90 passengers. Both types of coach are arranged with open compartments like those of the four-wheeled stock (fig. 11).

The ends are rounded so that the best possible speed can be reached against a head wind. The buffers and couplings on these carriages also are of specially light construction as not more than two of these vehicles are allowed to be coupled together.

Fig. 8. — Light 100-H.P. 4-wheeled rail motor coach, Wumag, Görlitz.

Fig. 9. — Interior of 100-H.P. rail motor coach.

Both the four and eight-wheeled carriages have already been tested and ride well and give a good performance. The eight-wheeled trailer was sujected to further special tests for riding qualities. It was loaded with the dead load of 7.5 t. (7.4 Engl. tons) and attached to a special experimental train run at speeds up to 132 km. (82 miles) per hour. It showed such excellent riding qualities under these conditions that most probably such carriages could be run at still higher speeds were a suitable form of motor available.

Fig. 10. — Light 175-H.P. 8-wheeled rail motor coach, Wumag, Görlitz.

Fig. 11. — Interior of 175-H.P. rail motor coach.

In addition to these rail motor coaches driven by petrol and Diesel engines a further four-wheeled carriage of the light type of construction already described was equipped with steam propulsion on the Dobel system. The tests that have so far been made show that this vehicle also is capable of giving a satisfactory performance, and rides well up to 90 km. (56 miles) per hour (fig. 12).

On the basis of the very satisfactory results obtained with these specially light four and eight-wheeled motor coaches and their respective trailers, the German State Railways have ordered further carriages of the same class. In order to permit faster running on lines

with more severe gradients, the four-wheeled motor coaches were specified to have Diesel engines of 150-H. P., and the four-wheeled trailers to have larger accommodation for an increased number of standing passengers.

In addition to the eight-wheeled motor coaches so far equipped with 175-H. P. Diesel engines similar coaches of the lightest construction were ordered for running at high speeds, to be fitted with 300-H. P. engines, and later on others with 410-H. P. engines. These Diesel-electric coaches have been designed with rounded ends and valances below the body framing for the purpose of reducing the air resistance. The trailers have been designed on corresponding lines and with driving compartments.

It is anticipated that these larger Diesel-electric coaches will have tare weights of 42.0 t. (41.3 Engl. tons) for the 300-H. P. unit, and 42.5 t. (41.8 Engl. tons) for the 410-H. P. unit, while the corresponding trailers should not materially exceed the present weight of 18 t. (17.7 Engl. tons).

Railways are having to meet increasing competition from air transport as well as from road vehicles. The result of this is seen in the growing practice of comparing the journey time by train with that generally taken by aircraft.

The State Railways are therefore contemplating the introduction of a fast service running at 150 km. (93 miles) per hour on the Berlin-Hamburg route, which is particularly suitable by reason of its few curves and level contour. The twelve-wheeled Diesel-electric high-speed carriage which is now being constructed by the State Railways for this purpose will be built in accordance with the practice prevailing hitherto in railway carriage design and therefore should not be confused with the so-called « rail-zeppelin » of Herr Kruckenberg. It will have second-class accommodation only, for about 100 passengers, as well as a buffet and a luggage compartment. At the high speeds contemplated, the external shape will exercise considerable influence on the performance; a close-coupled type of articulated unit is therefore being adopted, the space between the bodies being filled in with a large diaphragm and the ends carefully shaped, both front and rear being given the same form as the unit has to travel equally well in both directions, without being turned at terminal stations (fig. 13).

The double unit has two end bogies and a central articulation bogie (Jakobs bogie), these and the underframes being shrouded by means of sheet metal valances in order to avoid air eddies. As all re-entrant angles have a very adverse effect, the windows and doors are arranged as far as possible so as to be flush with the outside surface. Instead of buffers with round heads, a special form of buffer beam fitted with rubber blocks is employed and offers much less resistance.

Each of the outer bogies is equipped with a 410-H. P. Maybach motor and electric generator; the central bogie carries the two electric traction motors.

In order to economise weight, welding has been used extensively in the high speed unit. The estimated weight is 77 t. (75.8 Engl. tons).

This light type of construction is now being extended to single phase alternating current electric vehicles taking their supply from an overhead conductor. Designs are being prepared for vehicles in which the pover equipment is mounted in the bogies in the same manner as in the eight-wheeled carriages driven by internal combustion engines. Efforts are also being made to arrange for the transformers to be carried on the bogies as this arrangement would enable the lightest possible construction of the body to be used.

The motor coach stock developed by the German State Railways in conjunction with the various firms of carriage

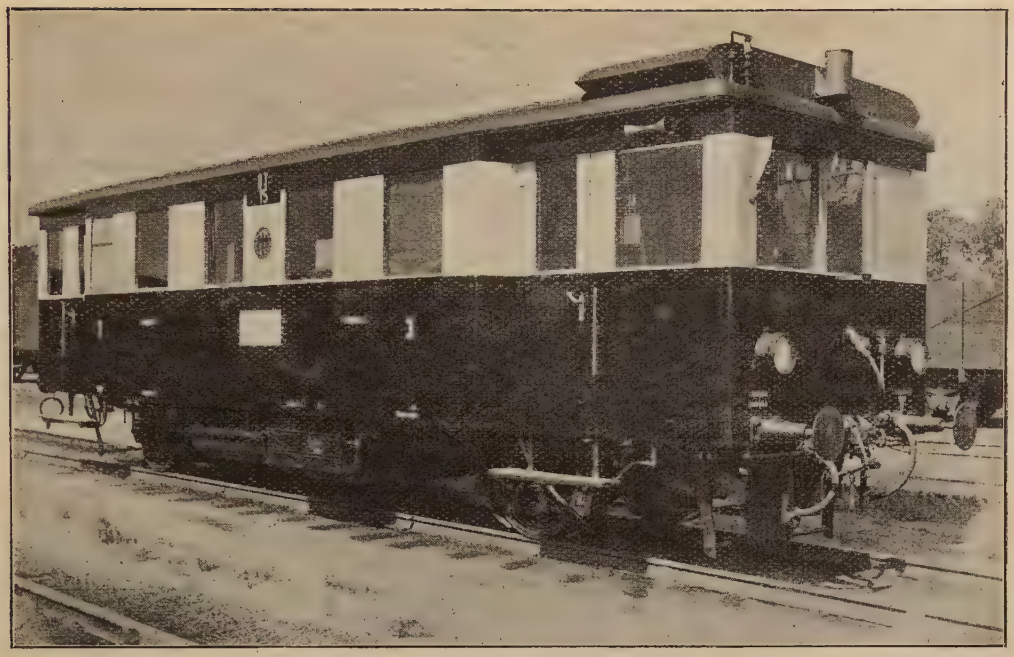


Fig. 12. — Light (100-H. P., Dobel) steam motor coach, Wegmann, Cassel.

Fig. 13. — 820-H. P., high-speed motor coach, Wumag, Görlitz.

Fig. 14. — Rail omnibus, by Henschel, Cassel.

builders has been supplemented further by rail omnibuses of a special type constructed by Messrs. Henschel & Sons, of Cassel. Thir firm has made a special point of reducing the unsprung weight of the axles and with this object in view has transferred the springing to the wheel discs. The first of the rail omnibuses fitted with rubber-disc wheels of this kind has only one driving compartment and it is therefore necessary to turn it round at terminal stations. The engine equipment is almost exactly the same as that of a large street omnibus (fig. 14). This vehicle has been in service for some months past. Further rail omnibuses of somewhat modified design are now being built by Messrs. Henschel for the German State Railways; these vehicles will have two driving compartments and a centre entrance. The design thus begins to resemble that of the motor coaches, and the weight also will approximate to that of the four-wheeled motor coaches previously described.

Some reference may now be made to Ing. Kruckenberg's propeller - driven coach, to which the name « rail-zeppelin » has been given. Light construction has been developed to a very advanced stage in this vehicle. The technical means by which speeds of 230 km. (143 miles) per hour have been obtained, are the combination of the best possible external form with the lightest possible weight, and the use of a form of drive that is particularly suitable for high speeds.

The propeller carriage has only one driving compartment and is built with a finely tapered tail-end; it can therefore attain its maximum speed only when running in the forward direction. The requirement of equally good running in both directions was sacrificed in order to render the solution of the problem somewhat simpler.

Reduction of weight was effected by using a tubular construction for the body framing. The forward end, and the sides below the windows have aluminium panelling, and the upper portion including the roof is covered with impregnated fabric.

The carriage weighs about 20 t. (19.7 Engl. tons) when empty, and runs on two pairs of wheels only, with the unusually large wheel base of 19.60 m. (64 ft. 4 in.). Sharp curves and points have to be taken at reduced speed, after putting into operation the device fitted to give the axles some freedom for angular movement relatively to one another, instead of maintaining them parallel as in normal running . The decision not to use bogies was due to the necessity for saving weight, and for having sufficiently high wheel loads for adhesion.

Under (4) above : *New light carriages for metropolitan lines.*

As stated above the German State Railways have had a train set of 8 carriages constructed for the Berlin metropolitan lines, in which the fullest possible use has been made of light materials, the intention being to determine from experiments with these vehicles whether the employment of these very expensive materials will prove economical under practical working conditions. Apart from this, light metals or light alloys have been used in the constuction of passenger stock to a limited extent only for various fittings that are not subjected to much stress or to the effects of weather ; such parts include ash trays, hat and coat hooks, lavatory fittings, door plates, interior panels, ventilators, net rack brackets, etc.

The first suburban carriages of steel construction for the experimental train weighed 45.5 t. (44.8 Engl. tons) in the case of the motor coaches, and 33.9 t. (33.4 Engl. tons) for the trailer control coaches. By very careful modification of the details and of the design as a whole it was subsequently found possible to reduce the standard weights for the class to approximately 38 t. (37.4

Engl. tons) and 27 t. (26.6 Engl. tons), i. e. by 16.5 % and 20.3 %, while retaining the riveted form of construction.

Experience in the use of welding for passenger stock was not available at that time, and it seemed that the use of light metal was the only possible economical way of effecting further reduction in weight in spite of the much greater cost of such materials. This supposition was especially justifiable in the case of a metropolitan electric system with its frequent starting, rapid acceleration, and heavy train loads, because any reduction in the dead weight of the carriages must react very favourably on the cost of electric power.

The contract for the 8 carriages for the metropolitan line train was divided, 2 of each of the motor coaches and trailer control coaches being entrusted to Messrs. Linke-Hofmann-Busch, Bautzen, and to Messrs. Wegmann & Co., Cassel, respectively. Designs were prepared by both firms in collaboration with the manufacturers of the light materials, and to obtain the widest possible experience the carriages were built to different designs.

The original designs had to be modified several times. The first intention had been to use nothing but light metal or light alloys, for the body, the interior finishing, the underframe, and the bogies, As however the light-metal carriages had to be as good as other steel carriages as regards strength to resist impact, and safety in operation, it was feared that should the 2 types of vehicle run into one another violently, the sills and horizontal members constructed in light metal might fail. Moreover, the inability of light constructional material to withstand indentation or buckling must be looked upon as a serious disadvantage. Once a piece has become indented from any cause it can no longer be relied upon to withstand the stresses for which it was designed. It was therefore decided that high-grade steel should be used for the underframe, especially for solebars, end sills and important cross-members, in the same manner as in the light suburban carriages of steel construction.

Further revision of the designs was necessary on account of the important advances made at that period in the manufacture of sections in light material. Previously all medium and large sections had to be bent out of light-metal sheet, but it is now possible to produce drawn sections with a high moment of resistance up to 160 mm. (6 5/16 inches) depth of web.

The improvements also made in the riveting of light metal enabled cold riveting to be done with rivets up to 16.8 mm. (0.66 inch) diameter.

Certain delays in the manufacture of the material had to be contended with, due to the fact that difficulties were encountered in the initial production of some of the new sections.

As a result of all these delays, the light metal carriages that were commenced as far back as 1928, were only completed by the end of 1930.

The bodies were constructed almost entirely of light metal, this being used in particular for the sides which were of framed construction, and for the details of the interior equipment such as grab handles, commode handles, net rack brackets, window frames, seat supports, etc.

Light materials were definitely ruled out in the case of the bogies for express carriages because of the severe stresses due to frequent starting and braking and the necessity of absolute safety in operation. The bogies finally used are exactly the same design and are constructed of the same materials as those for the light steel suburban carriages, and are interchangeable with them.

Messrs. Linke - Hofmann - Busch constructed the partitions partly of light metal, whereas Messrs. Wegmann used this material exclusively. The usual

wood construction was retained for the interior panelling by the former company, whereas Messrs. Wegmann employed light metal.

For the sliding doors Messrs. Linke-Hofmann-Busch used mainly cast silumin, and Messrs. Wegmann « Lautal » sheet.

It would have been possible to save weight by lightening the electrical equipment, but in order to avoid the development of a new design of motor no change was made.

The light-metal carriages being lighter than the light steel carriages resulted in a discrepancy between the ratio of loaded and unloaded weight, and the former type was therefore provided with an automatic brake adjustment.

There is very little difference between the light-metal and the light steel carriages either externally or internally. The interior of the former is distinguished by the silver-gray finish of the fittings, whereas bronze and brass are used in the steel vehicles (fig. 15).

The weights of the finished carriages are as follows :

	Metric (Engl.) tons.
I. Linke-Hofmann-Busch,	
Motor coach	34.35 (33.80)
Trailer control coach . . .	23.18 (22.81)
II. Wegmann,	
Motor coach	35.79 (35.22)
Trailer control coach . . .	25.09 (24.68)

The reason for the somewhat high weights of the Wegmann vehicles seems to be due to Wegmann having used light metal for certain parts that Busch built of thin wood.

The reductions in weight that have been achieved, as compared with the light steel suburban carriages weighing 38.0 t. (37.4 Engl. tons) and 27.0 t. (26.6 Engl. tons), are therefore as follows :

a) Reduction in Linke-Hofmann-Busch motor coach .	3.65 t. (3.59 Engl. tons) = 9.6 %
b) Reduction in Linke-Hofmann-Busch trailer control coach	3.82 t. (3.76 Engl. tons) = 14.1 %
c) Reduction in Wegmann motor coach	2.21 t. (2.16 Engl. tons) = 5.8 %
d) Reduction in Wegmann trailer control coach . . .	2.00 t. (1.96 Engl. tons) = 7.4 %

If the lighter design of Messrs. Linke-Hofmann-Busch proves to be satisfactory during the course of the next few years, and if, as a consequence, it is possible to build all new carriages to this design, the weight of a complete train of 8 vehicles (4 motor coaches and 4 driving trailers) will be reduced by 11.5 %. With the present price of power and load demands such a train, by reason of this saving of weight, would effect an economy of 5 000 Rm. per annum in the cost of electric power, and possibly a saving also in track maintenance. Against these economies must be set the not inconsiderable sum made up of increased interest and sinking fund charges for the capital involved, and the extra annual cost of carriage repair work. It will, of course, only be possible to form a definite conclusion as to the satisfactory qualities of these vehicles in operation and from the workshop point of view, after extensive experience in service over a period of at least several years; during that time special attention will be given to any symptoms of ageing which may reveal themselves in the light metal.

It should not be overlooked that these light metal carriages are being compared with light steel vehicles of riveted construction. In view of the remarkable success that has attended the use of welding in other steel vehicles, it is necessary to bear in mind that large savings in weight can be obtained by using welding for the steel type of construction, provided that the present heavy construction is lightened and high-quality steel employed. It is hardly likely that this type of

Fig. 15. — Light-metal carriage for the Berlin Metropolitan Railway.

Fig. 16. —Welded express-train carriage of the Netherlands Railways.

construction will increase the cost of the carriages. Due account has to be taken of the fact that the weights of the carriages will then approach much nearer to those of light metal construction. There is a probability that even if a considerable fall occurs in the price of light metals and light alloys, steel construction will prove to be cheaper than light metal construction.

It is hoped that the construction of light welded suburban carriages will provide reliable information on this point in the near future.

Netherlands and her Colonies.

The *Netherlands* Railways had the following all-metal vehicles at the 1 January 1932 :

Carriages for express trains and ordinary passenger trains :

AB d	21
C d	6
C 12c.	70
P d	11
D g	50
	158

Trailers for motor coaches :

AB^{e}*c*	11
B^{e}*c*	2
C^{e}*c*	11
	32

Motor coaches :

om BC	7
om BD	6
m BD	11
m CD	43
	67

This gives a total of 257 vehicles = 7.2 % of the vehicles of all kinds.

There were at that date under construction :

AB d.	25
D g	25
	50

In addition to these 50 carriages, the following carriages of new types have been completed, over and above the numbers of all-metal carriages at the 1 January 1930, as reported for the Madrid Session :

C d	70
om BC	7
om C.	6
	83

It follows that whereas the number of all-metal carriages at the 1 January 1930 was about 4.9 % of the total, the figure at 1 January 1932 had risen to 7.2 %, an increase of 47 %.

Of the carriages built after the 1 January 1930, the 25 AB *d* vehicles that were built since the 1 January 1932 were designed as corridor carriages. Instead of having sliding doors in the ends as in the German carriages, those of the Netherlands Railways are fitted with single hinged doors opening inwards (fig. 16).

The carriages are of welded construction.

The 70 all-metal vehicles of the C *12*c series may be said to be compartment coaches, even though there is only one outside entrance door to each section of two compartments. The seating is arranged in pairs of seats on each side of the central gangway running through the carriage. Each section of two compartments is separated by a partition running the full height and containing a sliding door. The two compartments forming each pair are separated by a low partition.

There are no entrances at the ends of the carriages and consequently no connecting gangways. The riveted all-metal type of construction has been adhered to (fig. 17).

Welding was again adopted for the latest luggage vans completed since the 1 January 1932 for fast trains. They have end entrances with gangways and vestibule connections, and one entrance in the side. As regards observation of the track no raised guard's lookout is provided but the baggage compartments are narrowed so that the track may be observed through the side windows of the widened guard's compartment (fig. 19).

So far the use of welding as a new method of construction has not led to any noteworthy reduction of weight in the 25 express-train carriages and 25 luggage vans.

For the new motor-coaches with internal combustion engines of the *om* BC and *om* C series, riveted steel construction has been retained. These cars have two engines arranged parallel to one another below the centre line of the carriage, and each drives the two inner axles of one bogie. Second and third-class accommodation is provided and there is a connecting ganway in the end. They are intended for suburban (branch line) traffic.

In the type of steel construction used

Fig. 17. — Riveted carriage for stopping trains, of the Netherlands Railways.

Fig. 18. — Interior of riveted carriage for stopping trains.

on the Netherlands Railways, like that employed in the German vehicles, the body and the underframe form one unit so that the sides may be regarded as forming part of the supporting structure.

Light metal or light alloys have not yet been used by the Netherlands Railways in the construction of passenger vehicles.

With regard to all-metal carriages in the Dutch Colonies, the Dutch Indies State Railways and Tramways, Bandoeng, report that on the 1 January 1932, 3.2 % of the electric motor coach vehicles with overhead collection were of all-metal construction. In addition there were at that date under construction another 12 motor vehicles of the same design with an overal length of 18.50 m. (60 ft. 8 3/8 in.), and 13 with a length of 14.50 m. (47 ft. 7 in.). No other types are being designed or built.

The 12 vehicles are of the third-class corridor type with entrances at the ends

Fig. 19. — Welded luggage van for fast trains on the Netherlands Railways.

Fig. 20. — Interior of welded luggage van on the Netherlands Railways.

and centre, whilst the 13 are luggage vans.

The body and underframe are constructed separately, but mounted rigidly together, the body structure supporting itself as an independent member. The 18.50-m. (60 ft. 8 3/8 in.) carriages have not yet been delivered.

Rumania.

The *Rumanian* Railways report that the number of all-metal carriages has not changed since the time of the Madrid Session, and that owing to the unfavourable financial conditions no new metal vehicles are either being built or projected.

So far the all-metal stock has been operated only on main lines, but in view of their greater safety and durability they will also be used on branch lines at some future date.

The body and underframe are separate in the existing-vehicles, the body being wholly supported by the underframe.

Sweden.

The all-metal carriages on the *Swedish State* Railways formed 10 % of the total number of bogie carriages at the 1 January 1932. Other types of passenger vehicles have not been taken into account because the State Railways intend to use nothing but all-metal construction for bogie stock.

At the date mentioned another 18 all-metal carriages were under construction. Two of these are saloon carriages, and the remaining sixteen third-class corridor sleepers, each having thirteen three-bed compartments (fig. 21).

The all-metal carriages are intended for use on main lines only.

The body and underframe forms an integral structure.

III. — Constructual methods and materials.

Germany.

1. *New welded carriages of all-steel construction for express-corridor trains, express trains, and slow trains.*

The bogies, underframe, sides, ends and roof, as well as a large part of the brake gear of the carriages are entirely of electrically welded construction. The advantages of arc welding as compared with the former riveted construction are as follows :

a) Complete elimination of the weakening caused by holes in the members;

b) Saving of material as a result of the better methods of jointing and utilising the various sections and sheets;

c) Reduction or elimination of the cover plates and angle pieces at joints which have been necessary in order to spread the stresses over an adequate number of rivets;

d) Replacement of cast parts by lighter welded parts.

St. 52 steel was used for the bogies, underframe, side stanchions and roof carlines. The special qualities of St. 52 are :

a) Its high elastic limit. When all the forces are taken up by the underframe it is safe to design many parts so that the stresses are in the elastic region;

b) High breaking strength. In railway operation, stresses may easily occur that are above the elastic limit as, for example, in shunting operations, or with normal impact. St. 52 steel gives an ample margin of strength to resist fracture;

c) High strength when subjected to vibration;

d) The addition of copper largely reduces the tendency to rust.

Fig. 21. — Riveted carriage for express trains, Swedish State Railways.

Fig. 22. — Sleeping compartment in 3rd-class sleeping car, Swedish State Railways.

St. 52 is a special steel that represents a pooling of the development work carried out by several firms in the German iron and steel industry in investigating various alloy steels having physical characteristics largely similar to silicon-steel. Tests have shown that St. 52 is capable of sustaining higher stress than St. 37, up to as much as 50 %; its tensile strength is 52 to 64 kgr. per mm² (33 to 40.6 Engl. tons per sq. inch), and its elastic limit not less than 36 kgr. per mm² (22.8 Engl. tons per sq. inch).

In constructing vehicles of this material, it may not be desirable to increase the stresses by 50 % for reasons of safety and to avoid vibration, but it is obvious that even without doing so, considerable saving of weight can be secured. St. 52 gives good results with modern welding processes. It is as good as special nickel-steel in physical qualities, and is given a high degree of resistance to corrosion by incorporating copper to the extent of at least 0.25 %.

The following table gives comparative test figures for the strength of St. 52 and for the St. 37 steel that was formerly much favoured :

Material.	Test piece cut from	Thickness of test piece, in mm. (*inches*)	Width of test piece, in mm. (*inches*)	Distance between punch marks, mm. (*inches*)	Breaking load, metric (*Engl.*) tons.	Load, kgr. per mm², (*Engl. tons per sq. inch*), Specified.	Load, kgr. per mm², (*Engl. tons per sq. inch*), Actual	Elongation, % Specified.	Elongation, % Actual.
St. 52	240 × 8	8.3 (0.326)	39.6 (1.558)	200 (7.87)	18.1 (17.8)	52/6' (33.0/39.4)	55 (34.9)	20	38
St. 37	NP 6	5 8 (0.228)	29.7 (1.169)	200 (7.87)	6.8 (6.7)	37/45 (23.5/28.6)	40 (25.4)	20	27

The girders in the various designs are constructed partly of standard rolled sections, partly of special sections, and in some cases of flanged plate.

The sheets for the panelling formerly did not contain any copper and like the rolled sections were made of thicker material on account of the possibility of rusting; the addition of copper to the alloy has rendered it possible to reduce the thickness.

Following previous practice pressed sheet metal has been used only for the seat supports. The use of cast steel has been avoided almost entirely.

In the three D-train carriages already completed by Messrs. Wegmann & Co., of Cassel, rolled sections have been used for preference.

For the girders of the underframe, which are subjected to twisting stresses as well as bending stresses, a box form of cross-section was chosen, as it is well known that this form of construction is the most suitable for resisting combined stresses. Provided they are not too long this kind of girder lends itself very well to the use of welding; the girders are held in a special frame during the welding in order to prevent distortion. Figures 23, 24 and 25 show cross sections of members of this type as used in the underframes.

From static considerations the beams shown in figures 23 and 25 are to be preferred to that shown in figure 24. With the former designs, however, pipe clamps, rubbing plates, stirrups, etc. can

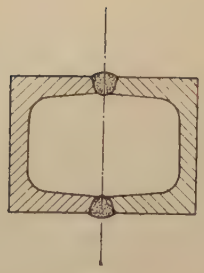


Fig. 23. — Welded girder made up of channel sections.

Fig. 25. — Welded plate girder.

Fig. 24. — Welded box-type girder with extension pieces.

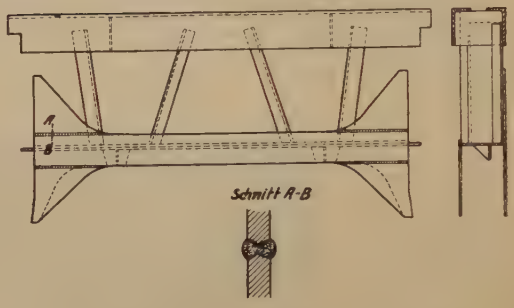
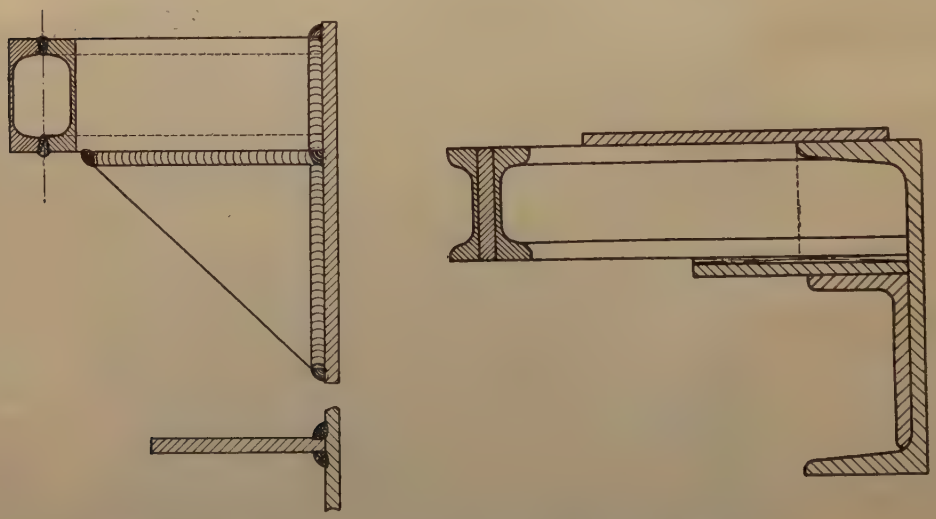


Fig. 26. — Welded buffer beam, Wegmann, Cassel.

Note — Schnitt A-B. = Section A-B.



Welded (new design). *Riveted (old design).*

Fig. 27. — Method of connecting cross-bearer with sole bar.

only be fixed by screws or welding. In the design of figure 24 the top and bottom plates are increased in width so that the above-mentioned details can be fixed by bolts and nuts, thus facilitating their removal when required.

It has not been possible to design the buffer beam as a box girder owing to the limited space available. It is therefore constructed in I form of plates welded together, and the top and bottom plates are extended at the ends so as to provide for the diagonal bracing of the underframe (fig. 26).

These extension pieces are welded to the straight plates by double V seams so as to avoid the extra loss of material that would result from shaping the plates. The end portion shown in figure 26 is welded together in a frame and afterwards built into the structure.

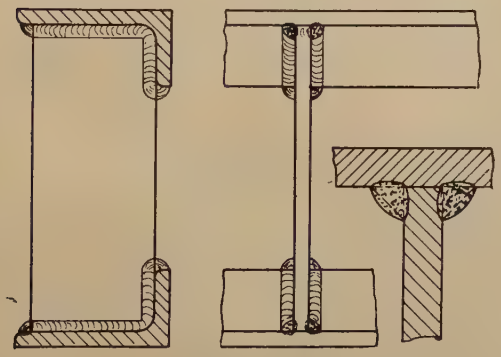


Fig. 28. — Welded sole bar.

The cross beams are joined to the sole bars by welding, bracket shaped plates being used to strengthen the joints. Figure 27 shows side by side the simple new method of jointing and the old riveted construction that has hitherto been standard.

The sole bars consist of two angle-irons joined together by a number of uniformly spaced stiffening plates (fig. 28). This design was decided upon as technically suitable for the welding process.

The forgings and castings that have hitherto been used in the underframe have been replaced, with advantage, by welded construction, and a weight saving of up to 50 % has resulted.

Figure 29 shows the bearing for the buffer equalising beam as constructed in the new light welded design and the old riveted design. Similarly, figure 30 illustrates the fulcrum block for the hand-brake lever in the two methods of construction.

Figure 31 shows a complete welded underframe.

Figure 32 is a cross section through the side of a vehicle. The lower plate angle *a*, the inner central flange angle *b*, and the upper flange angle *c*, are laid on supports with the sides uppermost that will face the inside of the panelling. The uprights, which are bent to Z shape out of 2 1/2-mm. (3/32 inch) sheet are clamped in position at the required distance apart. In order to prevent movement of the uprights during the welding process and to preserve accurately the dimensions and trueness of the window openings, the uprights are held firmly in specially prepared clamping frames. The welding of the uprights to the three runners *a*, *b* and *c* is proceeded with only after checking all the dimensions. The outer plates are laid down and tacked in place from below at a number of points.

The side is then turned over and welding of the sheets to the uprights is commenced. The method adopted is the progressive weave type of welding (fig.34). By welding first on one upright and then on another and by conducting the heat away as quickly as ever possible, distortion of the sheet panelling is limited to the minimum amount.

When running in service the body undergoes twisting stresses due to unsymmetrical forces exerted on the side bearing pieces, which vary in degree ac-

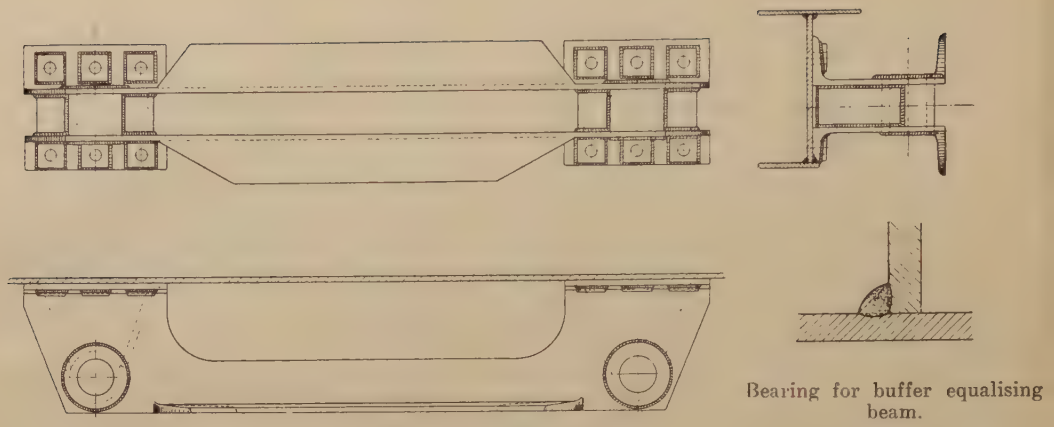
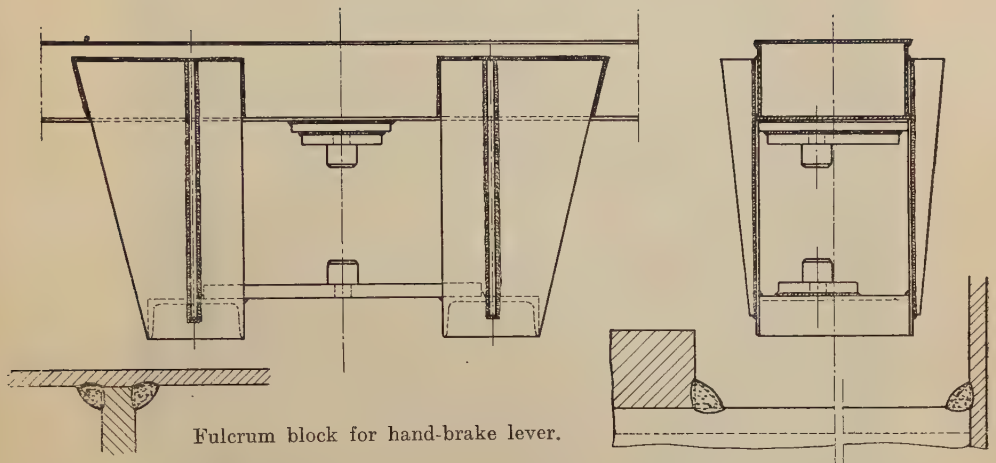


Fig. 29. — Bearing for buffer equalising beam.

cording to the condition of the track and running of the vehicle. It is necessary, therefore, to make the body also as stiff as possible against torsional stresses. This is possible when the underframe, sides and roof are welded together to form a rigid tube. The roof also has an important influence on the stiffness of the body. If the roof is too weak it will tend to vibrate itself and to transmit its movements to the sides.

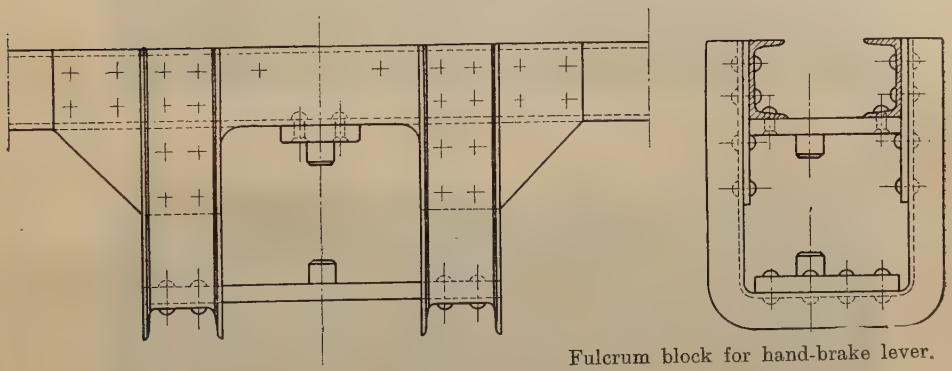
The *roof* is consequently provided with strengthened, welded carlines of flanged plate, which are considerably more rigid than the old carlines made of rolled sections and in addition show a saving in weight of about 30 %. The thorough stiffening of the roof in the longitudinal direction also can be seen from figure 35.

Statically the two longitudinal stiffeners form a bridge construction with the carlines acting as points of support. The roof covering, made of 1 1/2-mm. (0.059



Fulcrum block for hand-brake lever.

Welded (new design).



Fulcrum block for hand-brake lever.

Riveted (old design).

Fig. 30. — Fulcrum block for hand brake lever.

inch) sheet, is still connected to the carlines by riveting. In later designs welding will displace riveting at these points also.

Twisting tests have demonstrated the ample strength of the roof to resist distortion.

Special value has been attached, throughout the construction of the framework of welded carriages, to devising methods which are in every way as simple as those adopted for riveted vehicles. The underframes, sides, ends and roof are made as separate units and then assembled. This method has already shown itself to be the best for riveted carriages and it was only logical to adhere to the same system of erection for the welded vehicles, in which there is undoubtedly a possibility of distortion due to the effect of heat.

The trial runs have shown that the

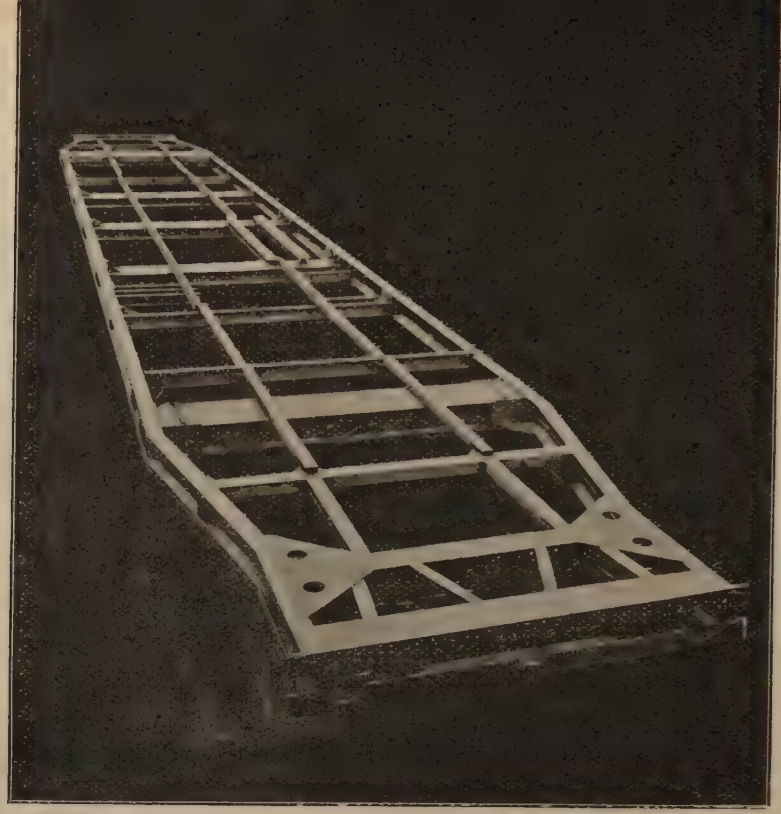


Fig. 31. — Welded underframe. Wegmann, Cassel.

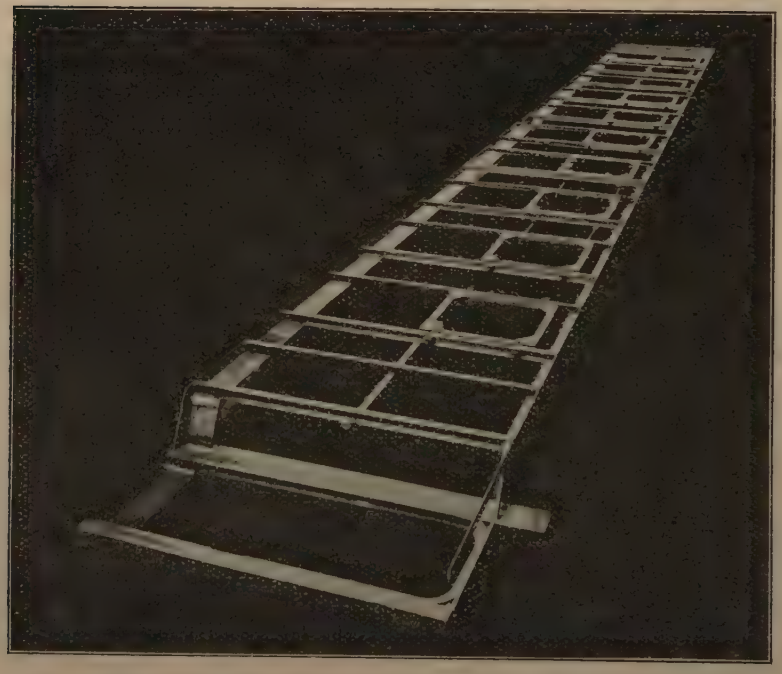


Fig. 33. — Framework for body side, Wegmann, Cassel.

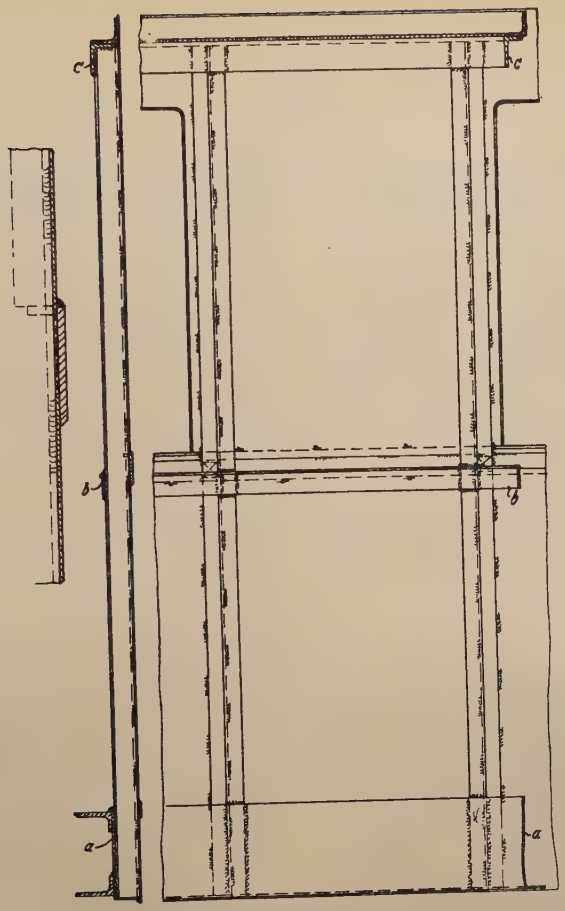


Fig. 32. — Welded body side, Wegmann, Cassel.

Fig. 34. — Welded side.

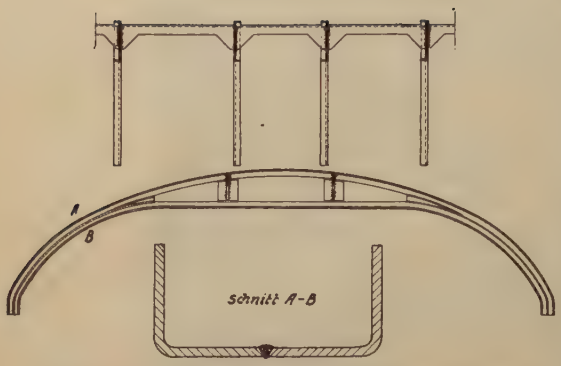


Fig. 35. — Welded carline, Wegmann, Cassel.

Horizontal seam for welding body side to underframe.

Fig. 36. — Method of connecting side to underframe in a welded carriage. Wegmann, Cassel.

construction of the carriages is satisfactory and that they have good riding qualities.

Much care has been given to avoiding the necessity of overhead welding, which is both more difficult and less reliable; no welding of this kind is employed even in the assembly of the underframe. The underframe is suspended from cranes and manœuvred as required to ensure that horizontal welded seams only are necessary.

For the same reasons, the sole bars are made up of two angle irons that are not butted close together; in this way the sides can be fitted to the underframe entirely by horizontal seams. Figure 36 shows how accessible and convenient this arrangement is for carrying out the welding operations.

A disadvantage of welded construction is that the first coat of paint cannot be applied until all welding has been completed. Several weeks are required for finishing a carriage, and it is essential for the finished steel frame to be sand-blasted again after the panelling has been fixed.

There is no risk of the inside of the closed box girders rusting as they can be made completely airtight, as is shown by many water pressure tests that have been made. In the case of the cross bearers that carry the bogie pivots it is not possible to avoid cutting some openings, and paint is applied inside them by compressed air.

It was decided to adopt the arc welding process for the welding together of the steel parts. At first difficulties were experienced with the selection of the electrodes. The use of the high-grade St. 52 steel required that the welded seams should be 50 % stronger than the corresponding figures for St. 37 steel. By using a new and specially prepared electrode the desired strength was actually obtained; the elongation, however, had to be greater in view of the vibration to which the body frame is subjected. It was found also that the material in the seams was so hard that is could only be worked by grinding. Following preliminary experiments, therefore, an electrode was finally chosen of somewhat less strength, but with a greater elongation. The preliminary tests were made on a bogie cross girder which a

series of thorough load tests proved to be free from any fracture in the seams, even when the girder was bent by the excessive loading. Figures 37 and 38 show the loadings and deflections at various stages, and the girder in its final bent condition.

As previously mentioned, the inside lining, the partitions and the floor of one of the two welded carriages were of the same wood construction as had previously been customary in D-train vehicles. In the other welded carriage the artificial wood « Histoxyl » was used, with oak veneer for the sides and partitions, and an additional saving in weight of about 1 ton was thereby effected.

The weight of the third class D-train carriage in riveted construction using the earlier heavy constructional parts was about 47.0 t. (46.2 Engl. tons), whereas the weights of the welded carriages were as follows :

a) Fitted with type III heavy Görlitz bogies and

1. Ordinary wood interior, Weight reduced to 40.1 t. (39.4 Engl. tons) i. e. by approx. 6.90 t.(6.8 Engl. tons) . . = 14.7 %
2. « Histoxyl » interior, Weight reduced to 39.1 t. (38.4 Engl. tons), i. e. by approx. 7.90 t. (7.8 Engl. tons) . . = 16.8 %

The above reductions are directly due to the method of construction. Further reductions obtained by collateral means were as follows :

b) Fitted with Type III Light Görlitz bogies and

1. Ordinary wood interior, Weight reduced to 37.5 t. (36.9 Engl. tons), i. e. by approx. 9.5 t. (9.3 Engl. tons) . . = 20.2 %
2. « Histoxyl » interior, Weight reduced to 36.5 t. (35.9 Engl. tons), i. e. by approx. 10.5 t. (10.3 Engl. tons) . . = 22.3 %

These reductions in weight when referred to the original figures of 47.0 t. (46.2 Engl. tons), are made up of the following separate items :

Direct saving in weight due to :

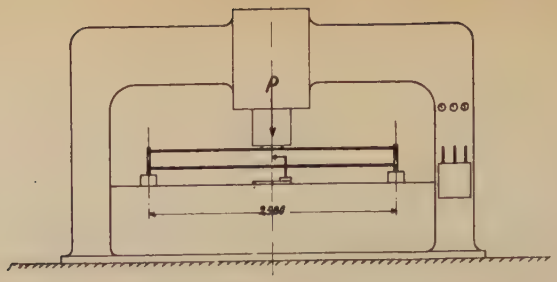
1. Lighter parts such as windows, heating, supports for luggage racks, lighting equipment, etc...	about	2.20 t. = 4.7 %
2. Welding of type III heavy bogies . .	about	1.18 t. = 2.5 %
3. Welding of body to underframe . . .	about	2.50 t. = 5.3 %
4. Use of high-grade steel	about	1.02 t. = 2.2 %
5. Use of « Histoxyl »	about	1.00 t. = 2.1 %
	Total :	7.90 t. = 16.8 %
Indirect saving due to :		
6. Ability to use type III light bogies . . .	about	2.60 t. = 5.5 %
	Grand total :	10.5 t. = 22.3 %

The percentage saving due to the use of welding for the bogies instead of riveting, referred to the original weight of the bogies without wheels and axles, — a saving of 1.18 t. on 11.0 t., is . . . . . 10.7 %

The corresponding saving in the body and underframe, exclusive of a saving of 1.02 t. by using high-grade steel, is 2.5 t. and this when referred to a total weight of 12.90 t. — 1.02 t. = 11.88 t., is . . . . . 21.0 %

For both the bogies and the body with underframe having a total weight of 11.00 + 11.88 = 22.88 t., the saving is 1.18 + 2.50 = 3.68 t. or a percentage saving of . . . . . 16.1 %

The savings in weight under 1, 3 and 4, amounting in all to 12.2 % have rendered it possible to use the light type of bogie. The further sav-



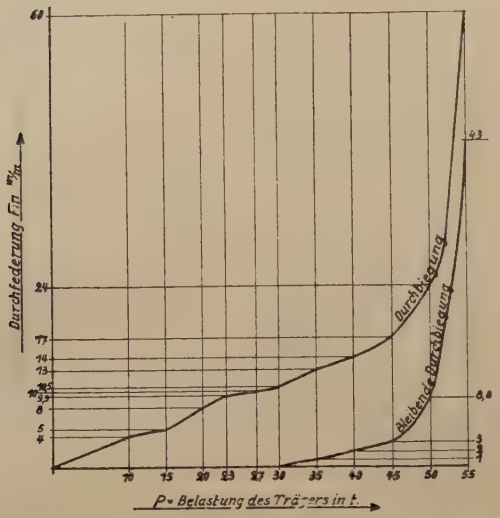


Fig. 37. — Deformation tests by loads on welded main cross bearer of a C⁴ü carriage.

Explanation of German terms:

Durchfederung, in *mm* = Deflection in millimetres. — Durchbiegung = Flexure. — Bleibende Durchbiegung = Permanent set. — Belastung des Trägers in *t* = Load on cross bearer in metric tons.

Fig. 38. — Welded main cross-bearer bent by excessive test load.

ing of 2.60 t. due directly to the latter is also partly the result of welding in the proportion of 5.3 to 12.2, i. e.

to the extent of $2.6. \frac{5.3}{12.2} = 1.13$ t.

The aggregate saving of weight due to welding is therefore $3.68 + 1.13 = 4.81$ t. on a total weight of 22.88 t. equivalent to . . . . . 21.0 %

In the case of the body and underframe the saving *due to welding and the use of high-grade steel* amounts to 3.52 t. out of a total weight of 12.9 t. or 27.4%

and for the bogies, body and underframe, the corresponding saving is $3.52+1.02=4.54$ t., which, referred to a total of $11.00+12.90=23.90$ t. is 19.0 %

Bearing in mind the direct saving of 2.60 t. obtained by the use of the light type of bogie, and that the proportion of this due to welding and high-grade steel is $\frac{(5.3+2.2)}{12.2} = 1.70$ t. we arrive at a total saving in weight due to welding and high-grade steel amounting to $4.54+1.70=6.24$ t. out of a total weight for the parts in question of 23.90 t.,or . . . . . 26.2 %

The great advantages of welding would appear to render it desirable to extend the use of the process as quickly as possible in carriage construction generally, especially as it cannot be said that the maintenance costs in the workshops will be any higher than for riveted construction.

Even though entire lack of experience may cause the first welded vehicles to be completed as an initial experiment, to come out dearer than the riveted carriages that have been built for years past, it is perfectly certain that for subsequent and larger orders the cost will come down not only to the same level, but appreciably below it.

In the same way the employment of high-grade steel particularly in conjunction with welding should not be dismissed more especially as the additional cost cannot be a considerable item.

The other methods of reducing weight that have been adopted, such as lighter wood fitments and special light designs of individual parts, can be adopted with advantage, and the more so in this case because any increase in cost will not be a recurring item.

As stated earlier, other welded D-train carriages are being constructed by various firms to different designs. Figure 39 shows the side of a carriage of the design developed by the « Waggonfabrik, Uerdingen-a/Rhein »; here again the design promises to result in comprehensive reductions of weight. In this case also considerable use has been made of girders of box form (fig. 40).

The *German State* Railways do not at present contemplate providing special heat insulation in the sides of welded carriages. Rather is it their intention to retain wood as the standard lining material, in view of its advantages as an insulation against both noise and temperature variations.

2. *New passenger vehicles on standard-gauge and narrow-gauge branch lines.*

Detailed particulars of the construction of these vehicles, which are for the most part of the usual riveted design, will not be given. With the exception of the 900-mm. (2 ft.-11 1/2 in.) gauge vehicles, use has already been made of high-grade steel. Individual components have also been manufactured in welded design. Only in the case of the branch line stock of 6.20 m. (20 ft. 4 in.) wheel-base recently ordered from the « Maschinenfabrik Augsburg-Nürnberg » has welded construction been adopted on the same scale as in the light 8-wheeled corridor carriages that are being built by the same firm; it is being

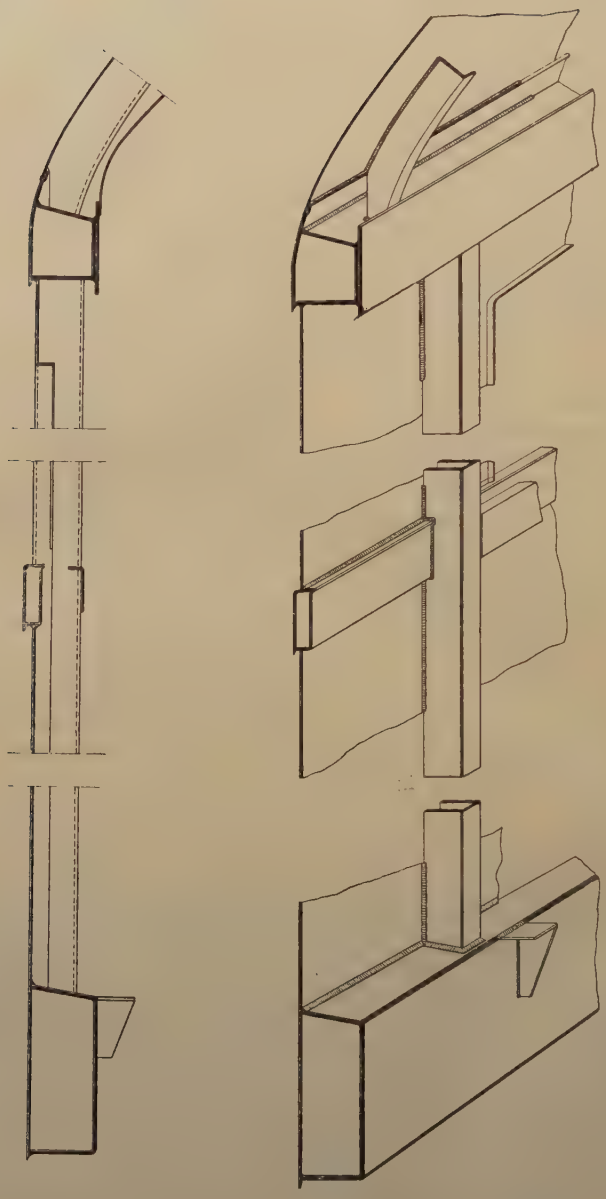


Fig. 39. — Welded body side, Waggonfabrik Uerdingen.

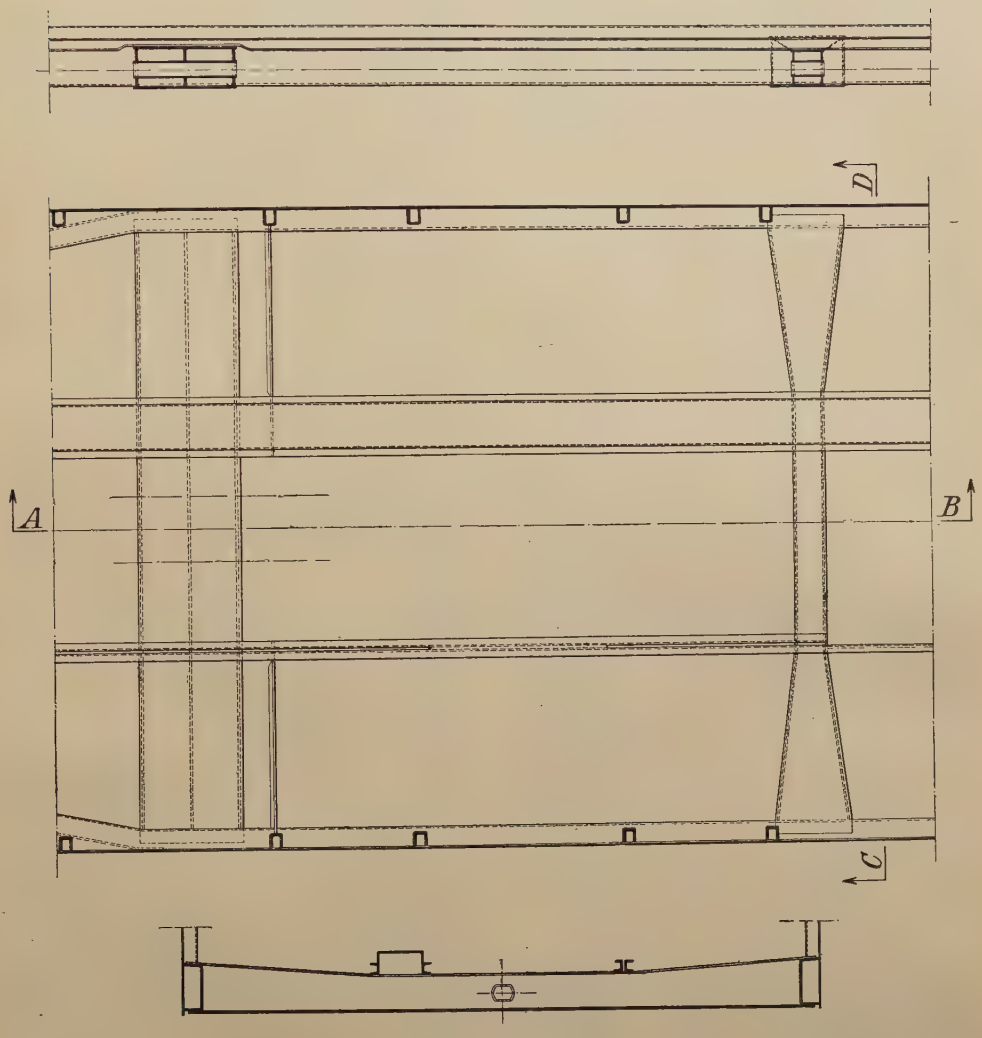


Fig. 40. — Part of welded underframe, Waggonfabrik Uerdingen.

employed in this case in order to reduce the weight as much below 15.0 t. (14.76 Engl. tons) as possible while retaining the existing standard of impact resistance.

3. *Light steel motor coaches and trailers for use on main lines and branch lines.*

These carriages were ordered concurrently with the development of the

welded D-train coaches and 8-wheeled corridor coaches, but the reduction of weight has been carried further because it is a condition of their service that they are used only with similar vehicles to make up short trains, and consequently there is no risk of large impact forces occurring.

Rolled steel sections have been largely replaced by bearers built up of plate in these vehicles, from the 4-wheeled light motor coaches up to those for use on 150-km. (93-miles) fast services. St 52 steel has also been used for external panelling. The method of construction described in detail under (1) have been adopted for these carriages.

Figure 41 shows a section through the side of a light 4-wheeled motor coach.

In this vehicle, which was designed by the « Wumag », of Görlitz, wood was at first retained for the roof covering with a view to reducing weight. For further contracts, however, the wood will again be replaced by steel as experience has shown that no increase in weight results from the use of thin copper bearing sheet steel.

The design of the underframe and body framework of the light 4-wheeled motor coach is shown in figure 42, and of the 175-H. P. 8-wheeled motor coach in figure 43.

4. *New light carriages for the Berlin Metropolitan Railway.*

As already explained, two half-trains were built for the Berlin Metropolitan Railway in which extensive use was made of light metal. The object in view was to produce vehicles in which the lightest possible construction was combined with a rigidity equal to that of the existing steel carriages. The question of the material to be used and the most suitable arrangement were vitally affected by the high cost of material. With a price ratio of no less than 20 to 1 the cost of light metal or light metal alloys cannot be reduced to less than five to seven times that of steel even though the weight of material used might be reduced to 1/3 or 1/4 of the corresponding weight for steel construction. The utmost economy in the weight of material used is therefore essential from the point of view of capital cost.

Endeavour has therefore been made to avoid the use of castings for all parts except those of complicated shape, and for simple parts to use high-grade rolled metal instead of cast aluminium; in this way a saving of up to 50 % is obtained. The reduction in cost depends upon the extent to which economies can be effected in working the material and in wages. Even if the manufacturing costs outweigh the difference in price, the advantage still remains of a weight that is less than one-half that of castings. This result is due to the fact that larger masses of cast material (silumin) are required than of rolled material on account of its lower strength, and the necessity of maintaining a minimum thickness of 3 to 4 mm. (1/8 to 5/32 inch).

Due to the reduced weight, is is worth while to use rolled metal also for window frames and doors although cast metal could be used for these parts. The simplest method of producing the sections required is to bend them cold out of sheet. If the material is too brittle, the sections can be bent, rolled or drawn under heat and afterwards re-annealed.

In using light metal as the constructional material, silumin is to be looked upon as the equivalent of cast iron, but apart from its lower weight it presents the advantage that it can be rolled and that bars produced in this way can be satisfactorily bent at a comparatively low temperature.

In deciding upon the shape of the bearers special attention has to be given to reducing the quantity of the expensive light metal to a minimum, and up to a certain point it may be profitable to increase the amount of work put into

the manufacture. For example, it may *not* be desirable to use simple U or angle sections as such, on account of their lack of rigidity, but to arrange these sections to form a hollow box-type of member. Since bearers of pressed or bent construction, owing to their shape, usually fail by buckling at some point, the removal of this risk is a deciding factor, particularly as the modulus of elasticity of the light metals is only 1/3 of that of steel and the resistance to buckling may also fall in the same ratio. It is for this reason that sections of robust shape should be employed when using light metal or light metal alloys.

For reasons of safety, those parts of the light-metal suburban vehicles that are highly stressed are still made of steel (*Si*-steel, St. 37 (23.5 Engl. tons per sq. inch), St. 42 (26.7 Engl. tons per sq. inch) and St. 48 (30.5 Engl. tons per sq. inch), although theoretically this composite construction is undesirable in view of the diverse characteristics of the two classes of material. In a framework that is statically indeterminate, this leads to a transference of load from the light metal to the steel parts, so that special care needs to be given to this point when working out the design.

When making the calculations the most important factor is the influence of fatigue. The maximum permissible fatigue stress is defined as the limiting stress that can be repeated at any time without leaving any permanent deformation. In the case of Lautal this limit is approximately 15 to 17 kgr. per mm² (9.5 to 10.8 Engl. tons per sq. inch).

In constructing the carriages two light alloys were used for the most part, Lautal for the framed members and interior, and Silumin (Alpax) for parts that were cast.

Lautal has a composition of 94 % *Al*, 4 % *Cu* and 2 % *Si*. It is guaranteed to have a breaking strength of 30 to 38 kgr. per mm² (19.0 to 24.1 Engl. tons per sq. inch) and an elongation of 18 to 25 %

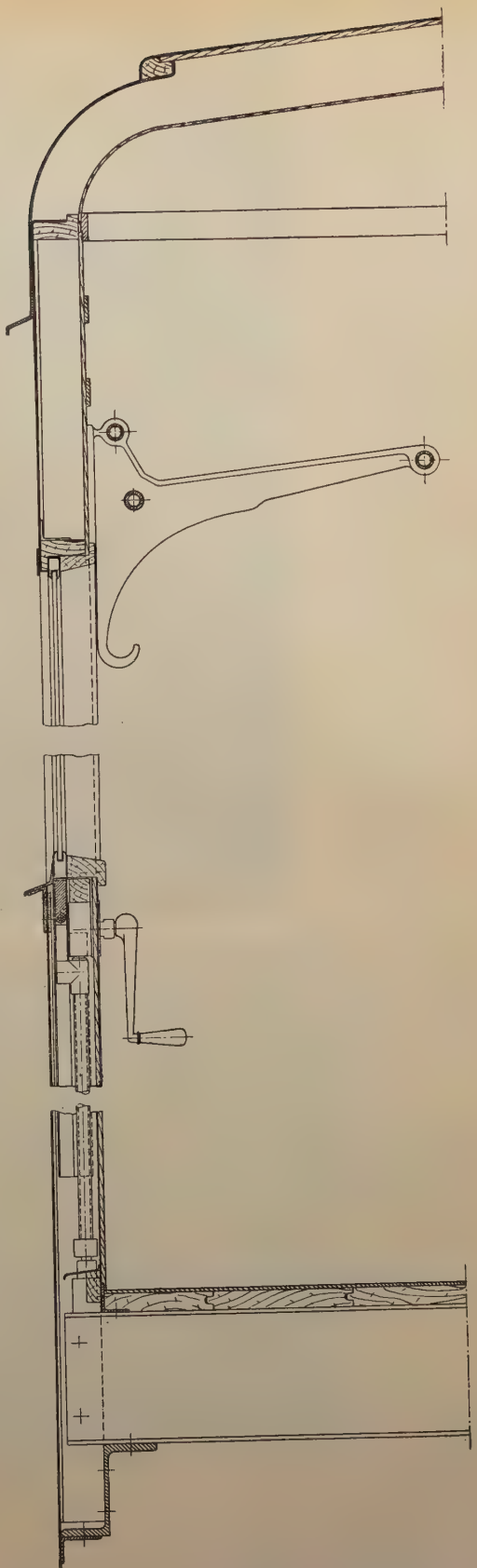


Fig. 41. — Side of 100-H.P. light 4-wheeled motor coach, Wumag, Görlitz.

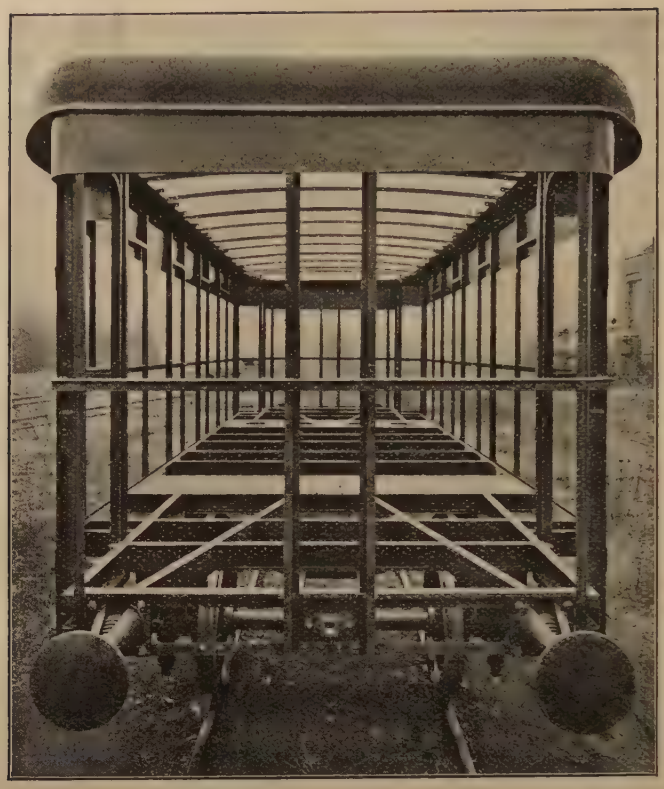


Fig. 42. — Body framing of 100-H.P. light motor coach.

The elastic limit lies between 19.0 and 20.5 kgr. per mm² (12.0 to 13.0 Engl. tons per sq. inch) with a residual extension of 0.2 %.

The strength of Lautal sheet may be as much as 42 kgr. per mm² (26.7 Engl. tons per sq. inch) with an elongation of about 20 %.

Silumin (Alpax) consists of 86.5 % *Al*, 13.0 % *Si*, with up to 0.5 % *Fe* as an impurity.

The materials used for the individual parts of the light-metal carriages are :

a) *Steel :*

Bogies.
Main longitudinals of underframe.
Main cross-bearer of underframe.
Buffer beams.

b) *Light-metal alloys :*

Body framework.
Central cross-bearer of underframe.
Light apparatus supports of underframe.
Cable ducts in underframe.
External panelling.
Roof covering.
Interior panelling (of one half-train).
Partitions.
Window frames.
Seat supports.
Luggage rack supports (silumin).
Luggage rack tubes.

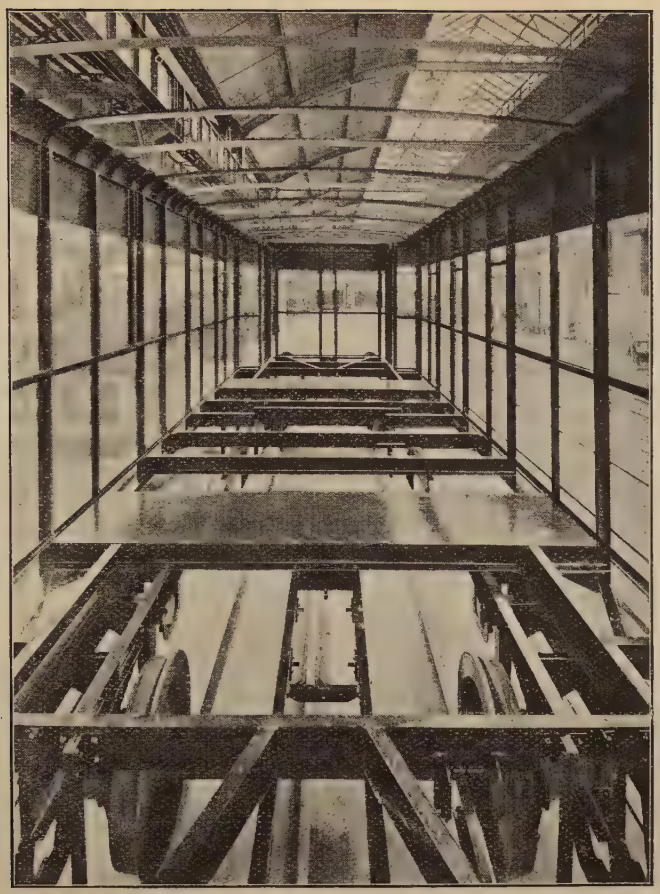


Fig. 43. — Body framing of 175-H.P. light 8-wheeled motor coach. Wumag, Görlitz.

Fig. 44. — Interior of light-metal metropolitan carriage constructed by Linke-Hofmann-Busch.

Commode handles.
Grip handles.
Sliding doors (partly cast Silumin; partly sheet Lautal).

c) *Plywood :*

Interior roof covering.
Interior panelling (of one half-train).

The thickness chosen for the sheets was from 2 mm. (5/64 inch) up to 6 mm. (15/64 inch) or more; special rolled sections of Z, U and L form were used for the frame. For the rivets and bolts light metal has also been used up to the present, whilst for rivets connecting two different classes of material, steel has been used by one firm and Lautal by the other. To prevent corrosion the surfaces of iron and Lautal, where in contact, and of course the rivets, have been coated with a non-acid oil paint.

Experiments have shown that metric screw-threads are not suitable for light metal because threated parts made of this material easily become loose, and the thread easily strips. It was therefore necessary to choose a coarser thread. Screws made of Lautal are smeared with grease in order to avoid risk of breakage when they are withdrawn.

Rivets are used for most of the joints. No use was made of autogenous or arc welding since the mechanical and chemical properties of welds in light metal by these processes are much too poor; in order to ensure that such joints will satisfactorily withstand the effects of continued vibration they must be carefully hammered, and this is hardly possible for the class of work in question.

To ensure that the Lautal rivets are a good fit after they are closed the holes are made only 0.2 mm. (1/128 inch) larger than the diameter of the rivets. As against the practice adopted in the steel vehicles, the number of rivets is made large and a comparatively small diameter chosen with the object of obtaining good contact everywhere for resisting the reaming pressure. The pitch of the rivets depens upon he magnitude of the forces and varies from 2 1/2 to 3 times the rivet diameter; the distance of the rows of rivets from the edges is from 1.6 to 1.8 times the rivet diameter.

The sides are designed essentially as framed structures. They are strengthened near the doors by special frame pieces because of the considerable compression and shear forces at these points, where of necessity the main framework has to be interrupted (fig. 44).

The external sheating is of 2 mm. (5/64 inch) Lautal sheets like the roof covering. To prevent any bulging of the sides due to the horizontal forces they are well supported by constructing the half-partitions at the entrances so that they assist to stiffen the body. The partition is of 2-mm. (5/64 inch) sheet and is joined to the door frames at the edge.

Figure 45 shows a section through the upper part of the Linke-Hofmann-Busch carriage. Wegmann have introduced an upper flange that consists of two [sections joined together (fig. 46).

Figures 47 and 48 show further cross-sections of the main girder of the carriage supplied by Wegmann.

Plywood is used for the inside panelling in the Linke-Hofmann-Busch carriage, and Lautal sheet in the Wegmann vehicle.

In the third class compartments the panelling is faced with linoleum up to the horizontal sills for the window openings. The upper part has a grained oak finish. In the second class accommodation the lower part is covered with fabric and the upper part has a mahogany finish. All the panelling material has its inside surface covered with linen for the purpose of heat insulation.

Some of the doors were constructed of Silumin castings, and others of riveted Lautal sheet. The riveted construction is both lighter and cheaper than the cast design, and has proved satisfactory in

service; it will therefore be adopted for the new Metropolitan carriages (Wannsee line) now in hand and also for any replacements (fig. 49).

Wood is used for the floors, as in the case of the steel suburban carriages.

The light-metal carriages are painted in the same way as the steel carriages. In order to ensure a satisfactory groundwork it was necessary to roughen the outer surfaces of the sheet panelling; this was done partly by sandblasting and partly with sand paper.

No difficulties were met with in bending and shaping the sheets in the workshops. The bending of the section material was more difficult as in most cases it had to be done by hand. The thin sheets were bent cold; the thicker sheets and the sections could be bent hot at a temperature of up to about 450° C. (842° F.). To avoid excessive distortion repeated annealing was carried out by means of a current of air.

It was found necessary to use a much increased speed for drilling. For cutting sheets and sections it was possible to use wood saws up to a thickness of 15 mm. (19/32 inch).

All riveted joints and surfaces in contact were coated with non-acid white lead in order to render them impervious to water or acid of any kind, especially the sulphur-laden products of combustion from coal.

The electrical equipment, the buffing and draft gear and the brake equipment have been kept the same as in the light steel carriages.

The saving in weight on a train of 8 carriages, as compared with the light steel vehicles, can be taken as about 11.5 %. It may be possible to improve on this when light metal or light alloy has been substituted more completely for parts that have still been made of steel. On the other hand, it will also be possible to effect noteworthy reductions of weight in the steel metropolitan carriages, by substituting welding for riveting and using high-grade materials.

The contract price, which does not represent the whole of the actual expenditure incurred, is about 60 % greater than for the steel type of construction. This prise is, however, a poor basis of comparison, since the carriages had to be built as individual units, whereas the manufacture of the steel wagons was fully developed on a quantity production and interchangeability basis; moreover, several of the experimental designs contribute largely to increasing the cost. It may be assumed that the manufacture of a whole class of the vehicles would result in a lower cost, more especially if there is a fall in the cost of materials.

The carriages have now been put into regular schedule service, after having been thoroughly tested in respect of adequate strength. It is not yet possible to come to any final conclusions as to the serviceableness of light metal carriages.

Holland and her Colonies.

In their new carriages of all-metal construction, the Netherlands Railways use steel for the body, underframes and bogies. The girders are built up of standard rolled section. Special sections and pressed sheet have not been employed. Cast steel is used for the axle bearings and guides, for the swing bolster bearing pieces and the spring supports of the bogies; on the other hand, no use has yet been made of light metals of light alloys.

Sheet steel is employed for the outside panelling; sheet metal and wood are used for the inside with a covering of pegamoid or fabric, and the partitions are constructed in a similar way. The floors are of wood and Celotex, covered with felt and linoleum; this construction gives good heat insulation and reduces noise.

Sheet metal is used for the roof.

The only heat insulation in the sides is that given by the air space between

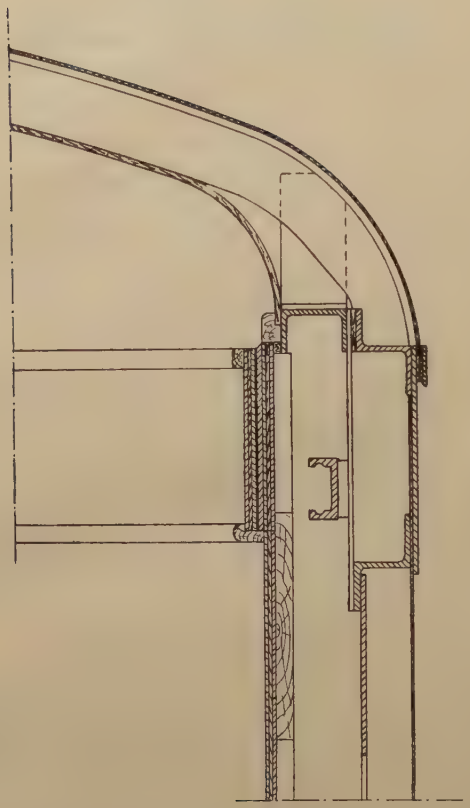


Fig. 45. — Top flange construction in the light-metal metropolitan carriage, Linke-Hofmann-Busch.

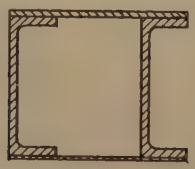


Fig. 46. — Top flange construction in the light metal metropolitan carriage of Wegmann, Cassel.

the inner and outer coverings. Celotex is used also for the insulation of the roof.

Formerly the steel plates were united

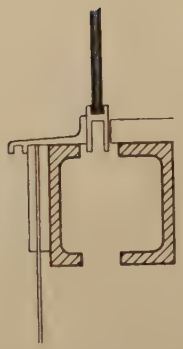


Fig. 47. — Web construction (Wegmann).

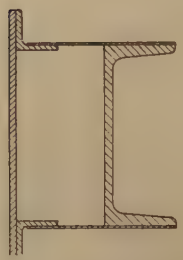


Fig. 48. — Bottom flange construction (Wegmann).

by riveting. The new passenger vehicles just completed have been electrically welded. Spot welding has been employed in addition to arc welding. No special measures have been adopted to prevent distortion or bulging in the neighbourhood of the welds. As an experiment welding has been employed in 50 carriages (express passenger carriages and express luggage vans), and the decision as to the retention of welding for the new vehicles will depend upon the experience obtained.

No reduction in weight has resulted from the use of welding.

In their vehicles of all-metal construction, the Dutch Indies State Railways and Tramways have also used standard sections for the girders and copper bear-

ing sheet steel (0.2 to 0.3 % *Cu*) for the exterior panelling. Sheet iron has been used for the inside roof covering of the passenger vehicles. In the goods vehicles the roof is of wood covered with rubber sheeting (leadrubber No. 3); in the other vehicles the covering is of copper bearing sheet iron. The bodies and bogies

Fig. 49. — Riveted light-metal door. Wegmann, Cassel.

are of riveted construction utilising the usual rolled sections.

The interior panelling is also of sheet iron, but wood is used for the partitions. The two layers of boards for the double wood floor are both tongued and grooved; the boards are laid transversely. The floor of the lavatory compartment is lined with sheet lead 4 mm. (5/32 inch) thick, and this in turn is covered with bitumen.

The wood roof of the goods vehicles has an inside lining of 3 mm. (1/8 inch) sheet iron which is shaped to suit the wagon structure and forms an intrinsic part of the anti-telescoping construction. All other vehicles are fitted with a double sheet-iron roof, the inner sheets being of 1 mm. (3/64 inch) thick material. The sheets used for the exterior contain copper.

Ventilation is provided by « Airvac » ventilators by the Honeypot Works, Darlington.

The steel parts are united by means of copper bearing rivets (0.2-0.3 % *Cu*), whilst the roof sheets are electrically welded to the carlines.

The management is of the opinion that the use of welding for all passenger stock in place of riveting is an advantage, even though no appreciable saving in weight is obtained thereby.

No use has been made up to the present of light metals.

Rumania.

The Rumanian Railways have no new vehicles under construction or in process of development. In the existing rolling stock, the bodies, underframes and bogies are for the most part of rolled sections. Less use is made of pressed sheet parts because this manufacturing process has not yet been developed in that country.

Light metals are not used in building these vehicles.

Sheet steel is used for the exterior panelling, and wood for the interior including the partitions and the floors. The roof is of wood covered with composition and sheet copper.

Adequate heat insulation is provided by the interior wood panelling.

The steel portions are united by riveting. The administration of this railway is in favour of welding and pro-

poses to introduce it in the construction of all future vehicles.

Sweden.

The *Swedish State* Railways use standard sections in their all-metal passenger vehicles; pressed steel parts are the exception.

Up to the present no use has been made of light metals or light alloys in building passenger vehicles. Sheet steel is used for the exterior panelling. The space between the inner and outer coverings of the sides is filled with a material of American origin « Balsam wool », manufactured by the Wood Conversion Co., of Chicago. As an experiment « Alfol » (light metal foil) is also being used in some carriages.

The wooden floor is of double construction with a layer of cork between.

Steel is employed for the exterior of the roof, and wood for the interior.

Riveting is used almost exclusively for uniting the steel portions. A few joints have been welded by the autogenous or electric process. No saving of weight has been effected by the use of welding.

B. — GOODS VEHICLES.

Germany.

I. *Ordinary goods wagons.*

The *German State* Railways do not at present contemplate the use of steel construction for ordinary goods wagons, because these simple vehicles would be heavier and more expensive, and difficulties would arise in the securing of certain classes of freight. At one time a number of all-steel open wagons were built, intended principally for transporting coal.

Steel wagons represent 6 % of all the available goods vehicles.

The all-steel vehicles were manufactured as far back as 1893 to 1924. The rolled sections and sheets that were used correspond generally to the St 37 material that is now general.

Steel with a copper content, or other steel alloys intended to prevent or reduce rusting have not been used in the construction of ordinary goods wagons; neither has any special rust-resisting paint been employed.

The underframes are painted with a coat of red lead, an oil-colour ground coat, and a glossy colour coat. Recently, as an experiment, layers of impregnated jute and strips of bitumen roof felt have been applied to the top flange of the girders so as to project on both sides.

Use has not been made in the building of goods vehicles of the metal-spraying process, or any other process of metallic protection against rust. Experiments with various spraying processes have not given satisfactory results, particularly in view of their expensive nature.

The only covered all-metal goods vehicle to be considered is the hinged-cover or lime truck in which no special consideration has to be given to protection against heat, or the draining away of condensation.

The steel parts of the underframe are united by riveting. Welding processes have not yet been introduced generally for ordinary goods trucks. A final answer to the question of whether welding can replace riveting in all vehicles of the all-metal type, and whether and to what extent reduction in weight can be effected thereby, can only be arrived at by exhaustive experiments. With this in view designs are being worked out to suit the special technique of welding processes.

II. *Bulk-material wagons for coal, coke and ore, earth-tipping and ballast wagons.*

Large wagons for transporting material in bulk, that are constructed for self-emptying, and the smaller self-

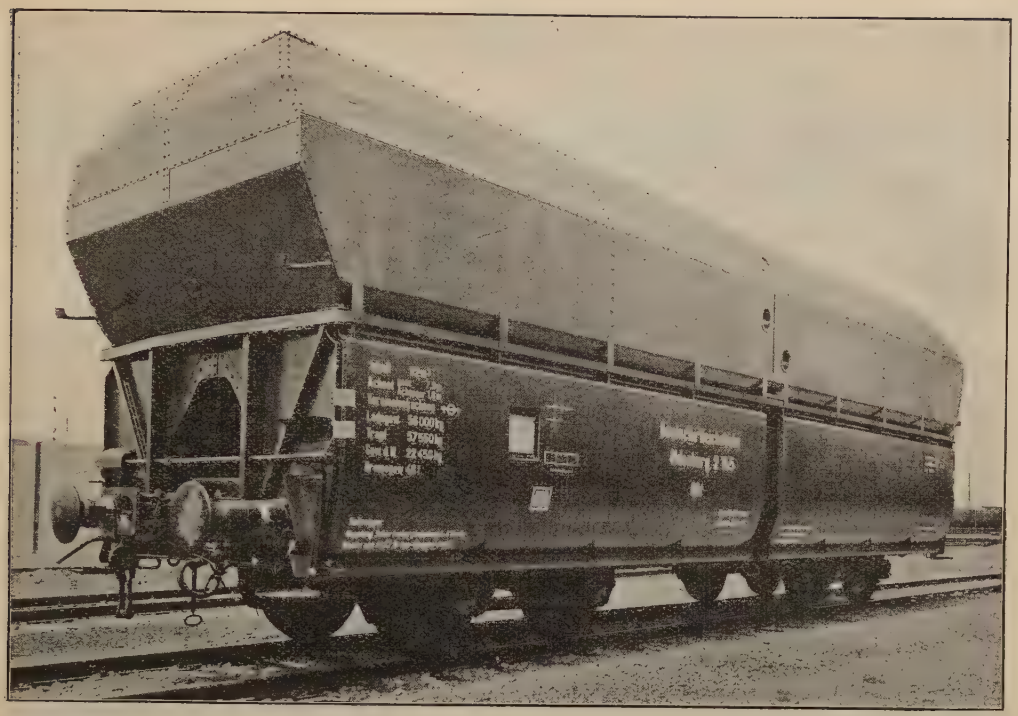


Fig. 50. — Self-discharging coal wagon.

Fig. 51. — Self-discharging grain wagon.

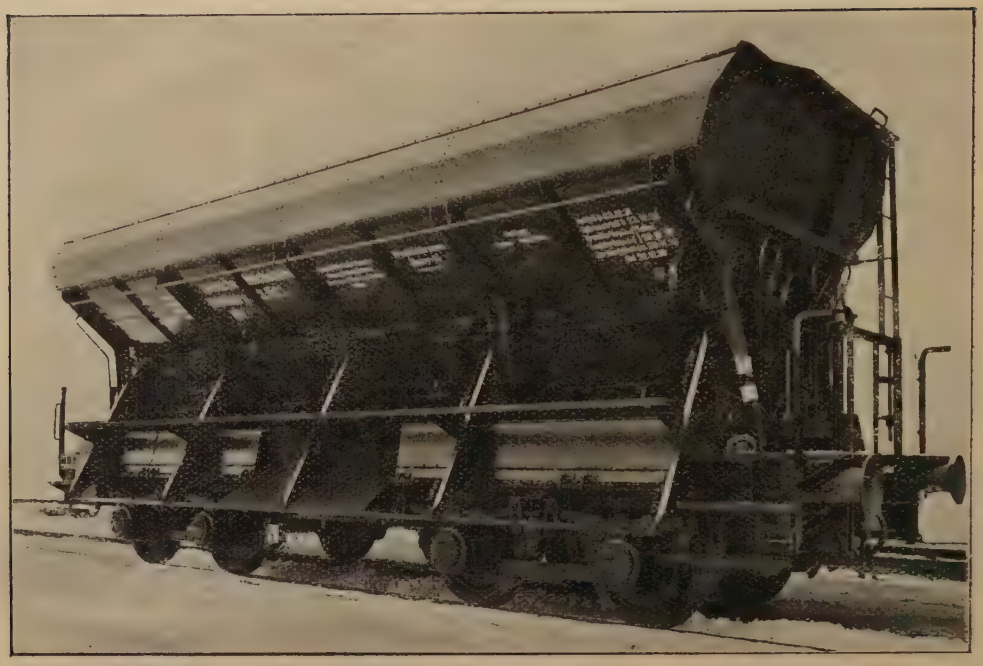


Fig. 52. — Self-discharging mineral wagon.

emptying wagons are used only for the transport of freight that can be shot. All vehicles of these types are of the all-metal design. Wood is not suitable for such vehicles, since the special shape of the self-emptier usually renders it essential to employ steel, and wood is subjected to too much wear and tear especially if the usual modern practice is in use of loading by machinery; the bulk material is then delivered from above and the vehicle receives the impact of a large mass of material.

By employing steel, increased space is available, and therefore a greater loading capacity.

Wagons of all-metal construction are very stable since the plates forming the body are designed to carry some of the stresses as well. Although of lighter construction, they are therefore well adapted to withstand the severe stresses of loading and unloading; this is all the more important in view of the fact that with self-unloading vehicles, loading and unloading occur at much shorter intervals.

The number of steel large-capacity wagons, hopper wagons, ballast wagons and earth-tipping wagons is 0.4 % of the total number of goods vehicles.

The main considerations to be kept in view when building these all-metal wagons are as follows : The permissible axle load and the maximum loading per unit length have to be utilised as fully as possible, and the maximum useful space has to be obtained for bulky materials within the gauge limits of the wagon profile.

For the main steel parts (plates and girders) of bulk-material wagons, St 37

St 52. Small capacity self-discharging wagons up to about 20 tons and all the ore wagons built hitherto are, however, constructed of St 37. The St 52 that is now used has a copper content of at least 0.25 %.

Four kinds of St 52 are used in the construction of the wagons, the precise compositions of which are left to the suppliers; the four varieties are :

a) Chrome-copper steel;

b) Manganese-silicon-copper steel;

c) Molybdenum-copper steel;

d) Maganese-copper steel.

Red lead is used for the first coat. No special paints are used for protection against rust.

In this case also there has been no adoption of metal-spray processes for giving a metallic protection from rusting.

No heat insulation is necessary in these wagons. Formerly the separate steel parts were united by riveting, but now electric-arc welding is also used. Welding is employed at all joints, and appears to be successful as a substitute for riveting. The experience obtained up to the present justifies the assumption that a saving of some 5 to 10 % in weight can be obtained by means of welding, according to the particular design.

Holland and her Colonies.

The *Netherlands* Railways have not yet come to a decision on the question of building goods wagons of the all-metal type. Nevertheless, they intend, as an experiment, to weld some large coal all-metal wagons. Their reason for taking this step is stated to be the reduction of maintenance costs, and the possibility of saving weight.

The number of steel coal wagons of older design is 3.1 % of the whole of the freight wagons.

In the majority of these wagons, steel is used for the underframes, body frame and body; wood is used for the body frame only in a few of the older vehicles.

The *Dutch Indies State* Railways and Tramways, Bandoeng, intend to employ all-metal construction for all their goods wagons, by reason of the economy and durability of such vehicles. In future sheet metal will be used for the floors.

No all-metal goods wagons have yet been put into service, however. It is anticipated that they will prove simpler and cheaper.

Rolled sections and sheets are used for the chief portions of the wagons, but no copper bearing steel is used.

A red-lead paint is used to give protection against rust. Metal spraying processes have not been introduced. No heat insulation is necessary in these wagons.

The steel parts are joined by riveting and also by electric-arc welding.

The railway authorities consider that welding can be substituted successfully for riveting, especially for the joints in the body. They do not think that any considerable saving of weight will result, and estimate this as 100 kgr. (220 lb.) at the most.

Sweden.

The whole of the wagons used by the *Swedish State* Railways for transporting iron-ore have been built of steel for 40 years past and there is no intention of departing from this method of construction. In addition to these mineral wagons, they have some special open wagons also of steel, for the transport of transformers, boilers, etc.

The reason given for building all-metal wagons is that wood is subject to too rapid deterioration.

Standard sections are used in build-

ing the all-metal wagons. The usual mixture of red lead is employed as protection against rust. Metal-spraying processes have not been introduced.

No all-metal covered wagons are built in Sweden, and consequently no question of heat insulation has had to be considered.

Riveting is still used for uniting the various steel parts. Some little experience has now been obtained with welding.

* * *

In concluding this report I should like to express my gratitude to all the Railway Managements, and Rolling Stock Builders who have so willingly placed at my disposal their experience in the development of all-metal construction.

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

12th SESSION (CAIRO, 1933).

QUESTION XI :

Competition between or joint working of railways and airways, or railways and roadways.

An investigation from the technical, commercial and contractual points of view. [1]

REPORT No. 2

(All countries except America, Great Britain, Dominions and Colonies, China and Japan),

by F. P. VILLAMIL,

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and E. D'OCON-CORTES,

Ingénieur au Service commercial, Madrid-Saragossa-Alicante Railways.

The Permanent Commission of the Association considered it desirable to include among the questions to be discussed at the next Session of the Railway Congress at Cairo in January 1933, the following thesis :

« *Competition between or joint working of railways and airways, or railways and roadways. — An investigation from the technical, commercial and contractual points of view.* »

The countries belonging to the Association were divided up, for the consideration of this question, into two groups, and we were honoured by being asked to report on the question as regards the following countries : Germany, Belgium, Bulgaria, Denmark, Egypt, Spain, Finland; France with her Colonies and Protectorates; Greece, Italy, Luxemburg, Norway, Holland and Portugal and their Colonies; Rumania, Sweden, Switzerland, Czechoslovakia, Turkey and Jugoslavia; we also requested the Organisations belonging to the Association to send information on this question.

With this object in view, we prepared a Questionnaire, which we sent to all member administrations in the countries indicated above, grouping on the one hand all points relative to the regulations governing the relations between the railway and the automobile, and on the other hand those concerning the relationship between railway and airway.

Railway and automobile.

General considerations.

The extraordinary importance that the question of road motor transport has for the railways is generally known; it can even be said to be at the present time a factor of the greatest interest whilst

(1) Translated from the Spanish.

through the conjunction of special inherent circumstances it is not only very complex, but at the same time most indeterminate.

From an examination of the replies to the questionnaire issued with the object of collecting the necessary information so as to be able to judge of the state of the subject in each country, it appears that everywhere this question causes the most serious preoccupation; solutions to the problem are being sought for everywhere, but a really good one has not yet been found. The measures that have been taken have shown themselves to be but palliatives of a more or less general character; but the essence of the problem still exists.

The competition of the road motor forms what doctors call a general infection, and consequently one upon which it is difficult to operate. When the ill is localised and the competition reveals itself in a precise manner over a given line, it is possible to cure it in most cases; what is difficult is to find a general formula applicable to all cases; each case requires its own remedy.

When this competition first began to be appreciable, in 1926, the railway administrations endeavoured instinctively to meet it by their own resources; they soon found, however, that there was a fundamental factor with which they could not deal, a factor which was, however, so important that it formed the root cause of the competition and inevitably involved the intervention of the public authorities.

When considering the history of railways from the beginning their importance and their considerable influence on the life of the nations from their introduction will be observed, this importance and influence standing out much more clearly than in the case of the automobile at the beginning of its industrial development.

From their very beginning, railways were recognised as having the character of a public service and as being practically a monopoly, as there did not exist any possible competition with this method of transport; the operation of the railway was therefore regulated by submitting it to restrictive legislation under the permanent control of the State.

The automobile at first took the place of horse vehicles and had its function been limited to the role assigned to such vehicles, no special problem would have arisen for the railways. In time, however, the motor vehicle extended its sphere of activity and at a certain moment began to trespass on the railway field and compete with it, as in no country had the Government foreseen its present development and the consequences thereof. That this competition was able to establish itself was due above all to this lack of legislation.

The railways had been obliged to build their own lines; the Governments have always considered among their ineludable duties the construction and maintenance of ordinary roads. Theoretically any transport could be carried out over these roads which also could be freely used whatever might be the distance to be covered, but in practice their field of action remained extremely limited.

The various orientations of political ideals had their repercussion during many years on the conception of the power of the State as regards the construction and maintenance of the ordinary roads; at certain times tolls were enforced and at others these were suppressed and only duties of an industrial nature were required of the horse traction; but the maintenance of the ordinary road was always considered as incumbant on the State.

The automobile found the roads already made; there was no obstacle and no limitation to its use as regards industrial transport and it soon developed enormously.

While the railway has always had the

character of a large industrial undertaking, the automobile on the contrary acquired from the start a definitely individualistic character.

This in itself made it very popular and created an immense number of private interests, most of which were for the individuals concerned their principal means of livelihood. Industrially it represented a stimulus and it was relieved from the point of view of social legislation from certain restrictions, including legal restrictions. We know of many cases of whole families consisting of eight to ten persons operating a motor service and who, apart from the direct interest they give to working the service, do not comply with the requirements relative to the legal working day nor to the maintenance of the vehicles and while acting as trade representatives, even go as far as to act as intermediaries as regards banking operations.

The railway administrations having had recourse to their respective States for help and protection by means of legislation equalising these conditions of existence of the two methods of transport, the said States could only deal with this in two ways : either by imposing direct or indirect taxes on the road transport undertakings, or by relieving the railways thereof.

The first system was and still is unpopular, just because of the private nature of the road services; the second was contrary to the interests of the State itself.

In all countries the railways form, for the State, a source of revenue easily collected at little cost, and one which the revenue department can handle with sureness.

The imposition of high taxes on road vehicles involves the organisation of a new revenue control, which is always difficult and costly.

To this question the whole of the Administrations consulted have replied unanimously. Leaving on one side the manifestly unequal conditions under which the railways have to meet motor competition, owing to the costs which the restrictions imposed in the clauses granting the concession of the lines involved the railways in charges which do not bear on the operating costs of the road motor services, the unjust proportion between the transport tax, which falls almost exclusively on the railway operators, while usually this tax does not apply to goods transport by road, and in a few cases that of passenger traffic, although these transports are much less important than by railway, must be mentioned.

As regards the rates, their lack of elasticity with regard to the railways, is known, even when the rates are being lowered. The operator of a road motor service alters his rates in most cases at will, or else is not obliged to make them known more than a few days in advance when it is a question of passenger services, and thus avoids all hindrances legally imposed on the railways in this respect.

As an exception the case of *Finland* must be mentioned, as in this country the rates of the automobile services have to be checked by the competent authorities in the same way as the railway rates have to be checked by the Ministry.

At the present time there are road transport undertakings which have already lost the individualistic or family character, but they are still few in number relatively to the total road motor traffic, and in addition they have in no case become as yet of really great importance.

Taking everything into account, it is extremely difficult to estimate the damage caused by road motor transport to the railways, seeing that this competition is domestic and that its development has coincided with the world wide economic crisis which has so heavily weighed upon the financial results of the railway administrations.

Moreover, the topographical condi-

tions of the countries, as well as the greater or smaller number of large centres of production and consumption have also influenced to a greater or lesser extent the intensity of this competition.

This last factor is, in our opinion, of the greatest importance as since they have been exploited industrially, the road motor services, as is only natural, have endeavoured to find the most simple methods of obtaining profits and start to work not over new roads but on roads already existing and served by the railway.

In all cases the competition shows most clearly that the rates which have been used by the road motor services have always been based on those of the railways for the same distances, by slightly altering them, the essential condition to compete with the railways being to draw a good profit from the automobile in the two directions.

In order to be sure of the vehicles being loaded in both directions, the traffic between the two points served by the road motor must be reciprocal and of considerable volume; if this is not so, the road motor service will not pay. Thus the competition has been felt most seriously in those countries which have a large number of industrial centres manufacturing different products which are used on a large scale, and which demand the exchange of materials in considerable quantities.

Another important circumstance bearing on this question is that of the capacity of the railway as compared with that of the road motor vehicle. If we make a rational choice of values relative to the capacity of a road motor vehicle as compared with that of a railway train it can be said that the ratio of these capacities in the case of goods is approximately 1 : 75; in the case of passengers this proportion falls considerably, but always remains higher than 1 : 20, and it is clear that under these conditions the road motor services will take the parcels traffic and traffic of small tonnage, but cannot function if obliged to deal with large volumes of traffic.

On the other hand, if the direct costs of transport are considered at a given moment, only taking into account the train-kilometre cost, as compared to that of the automobile-kilometre, there is a relation between these values, when selected in a rational manner, of the order of 1 : 3. If we consider the value of the rolling stock of the train and compare it to an automobile, by getting out the relationship which exists between the periods of amortization required by the nature of one and the other stock, we come to the conclusion that the ratio of the cost of the train-kilometre to that of the road motor-kilometre, including the amortization of the rolling stock forming the train and the automobile, is of the order of 1 : 6; comparing this ratio to that of the capacities, we see that it is possible, leaving aside all other considerations, to obtain, in the case of the railways, a much lower price of transport than that by road. If provision were made for the maintenance and for the construction of the track both for the railway and the road motor, the competition of this latter with the railway would be difficult. As regards the track, it is a question not only of what we may call the open road but equally of other installations. The road motor uses the public highways and utilises them for standing grounds which enables it to offload goods and passengers at any building. This means in the case of the road motor that this form of transport has the advantage resulting from saving the costs of constructing its own buildings and enables it to convey goods from door to door.

In addition, the general charges of the railways must also be taken into account as these remain nearly constant between certain limits of the traffic.

These traffic variations in the case of the railways are very great whereas in the case of the motor services they are, in comparison with the former, very small, i. e. the road motor vehicle with a very small tonnage earns the money necessary to meet the general costs, whereas in the case of the railway the traffic has to be heavy to do so.

Moreover, there is no doubt that the motor services have altered very profoundly the fundamental principles of railway rates : that of the differentiation of rates according to the value, and that of the rate depending on the speed of transport. The road motor, when carrying goods, makes out its contract with complete liberty : most often it deals with the weight, at other times with the volume. In one case as in the other, the indemnity for damage is independent of the carriage itself and is covered by a special insurance; the price of the carriage is therefore independent of the value of the goods.

As regards speed of conveyance, the reasons for the difference between express and slow goods do not exist in the case of the road service; what interests the latter is to carry out the journey as quickly as possible so as to use the vehicle to the best advantage; it prefers to make the largest possible number of journeys with less profit per journey than to work fewer journeys at a higher rate.

Most Administrations consulted have not been able to divide up the information relating to the receipts the road motor transport undertakings obtain from their services. In certain cases in which such data can be estimated it is at once seen that the amount of these receipts has to be considered, seeing that there are quite a number of firms only able to meet their overhead costs with difficulty, and that there are many who ought to give up operating as they are making no profits.

Situation and extent of the competition.

The general impression is that competition tends to increase, especially as regards passenger traffic, although generally limiting itself to narrow areas. As regards goods traffic, the activity of this traffic does not develop so rapidly; nonetheless in most countries it is expected that the ill will be aggravated increasingly in the near future.

Nearly all the Administrations who have answered the questionnaire appear to find it difficult to calculate the proportion in which the competition of the road affects the railway traffic. This is especially due to the fact that the diminution of receipts, in recent years, of most undertakings due to the falling off of traffic is closely connected with the financial crisis affecting world production, this latter being the principal factor which is restricting the normal development of the railway industry. There are countries, however, where it is clearly proved that certain traffics carried to-day by road motor have been taken from the railway and the result has been a deficit in the receipts of these Companies.

Passengers.

As regards passenger traffic, *Germany* quotes a figure of 250 millions of Reichsmark per annum. *Belgium* calculates the number of passengers the road motors have taken from the railway as 80 000. In certain *French Colonies and Protectorates* in Asia and Africa, the number of passengers using the railway only represents 10 % of the passengers moving between towns in these countries; finally in *Switzerland* the figure of passenger traffic has fallen off annually, as a result of this competition, by 10 million francs, i. e. 6 % of the total railway receipts.

In *Spain* the two principal Companies estimate that they have lost 16.2 % of their passenger revenue.

Goods.

The consequences of the causes given above are that the receipts taken from the railway by the competition of road motor transport undertakings are always very difficult to determine; as a general rule it can be stated that the lorry carries the goodd which require the greatest speed or which most easily carry high prices. Generally it is a question of goods included in the highest rated railway traffic and as this competition grows its influence will be felt more markedly in the reduction of the railway revenue. Germany evaluates this falling off as being approximately equal to the loss in the passenger traffic. *Sweden* estimates that this reduction is approximately 25 % of the receipts in 1929. In *Denmark* the proportion is 16 %, and *Switzerland* considers that the annual receipts lost through goods traffic being carried by road is 20 to 30 million francs.

In *Spain* the two principal Railway Companies calculate that the goods transferred to the road correspond to approximately 5.7 % of the annual amount of the corresponding receipts.

On the other hand, there is no doubt that the growth of the automobile industry largely supported by the development of the road services brings the railway companies an increase in traffic by carrying the necessary materials. This is especially the case in countries where there is no such industry, seeing that the imports are carried by railway,and also by the far from negligeable traffic resulting from repair and maintenance materials, consumable stores, such as petrol, oil, pneumatic tyres, etc., although in no case is this traffic sufficient to make good the loss represented by the traffic taken away by the road motor services.

As regards the feeder traffic which the automobile might bring to the railway, it is in most cases of little importance. Actually in most cases the services introduced, whether for passengers or goods exist between places already served by the railway, as it is much easier and more profitable for undertakings dealing with this sort of work to take advantage of already existing traffic currents than to take the risk of working lines which would only serve to exchange goods and products between places not yet served by the railway.

In some very rare cases only are feeder lines established by private individuals, not belonging to the railway, and when it is a question of setting up such services for competing with other lines working a service parallel to the railway, but the traffic of which could be diverted partly back to the railway; the railway administrations must meet the lack of means of these undertakings, either by direct contributions at it is generally a question of a large number of small traffics, or by subsidising them as contractors of public services.

Automobile services serving large centres on a line parallel to the railway, although some little distance therefrom, can live by grouping together small consignments in one lot; on the other hand, when it is a question of connecting each point to the nearest railway station, instead of a single line, as many lines as there are centres of population along the service parallel to the railway, although each of them has little traffic, must be set up.

National interest of the question.

The great complexity of the problem is at once apparent when the above circumstances and considerations are taken into account.

There is no doubt but that the automobile has exceeded the rational limits of its activity relatively to the railway, but there is also no doubt that even supposing that this were not so, and that this activity had remained within smaller limits, the competition against the railway would always exist.

It is also evident that the development of the road motor has completely upset the financial position of each country, and as it is undeniable that the road motors cannot, at least for the moment, replace in any way the railway, neither from the point of view of capacity and volume, nor from the point of view of price, the Governments have been obliged to intervene in this question in the national interest.

Moreover, the railways represent an enormous capital investment. They can be considered in each country as the industry having involved the greatest first establishment cost, and their ruin would cause grave financial and credit complications in the countries.

It is consequently a matter of national interest in each country for the State to intervene so as to introduce a just and prudent equilibrium in the legal conditions governing transport by railway and by road. Al the Countries are of this opinion and the question is being investigated universally.

Legislation.

The legislative measures which result from studying this question are more or less radical, more or less efficacious, but everywhere at the present time special legislation has been introduced. If the question is examined from the point of view of the State, obviously the development of the road motor transport representing industrial progress and which properly looked after can render great services to the national economy, cannot be strangled. The Railway Administrations however must not hope for too much from the intervention of the Governments, which can intervene by imposing on the two methods of transport equal taxes, after taking into account the special circumstances of the construction and maintenance of the respective roadways and, after distinguishing between transport made exclusively in the private interests of a manufacturer, farmer, or any particular individual, and those which are carried out in the general public interest. It must be added that the Governments, to protect the railways without killing the automobile services in cases where the latter's existence is justified, favour by means of special or less severe legislation the lines which are set up as feeders to the railway and prohibit or tax more heavily lines parallel to the railway; but all this will still not suffice to meet the competition of the road motor vehicle with profit.

It is certain that the evolution of the railways has taken into account the necessity of their industrial development in the same way as the other industries desiring to adapt themselves to present conditions, and today the road motor vehicle, a real stimulant in this sense, has brought out more strongly the need for the railway to be organised in a more industrial and commercial manner.

This transformation does not depend only upon the undertakings themselves : it also depends on the action of the States, but the intervention of these latter in this question should be of a totally different nature to that made to confine the road motor services within their proper sphere of action. We have in mind the necessity of having the legislation relative to the railway modified by the States, in order to give more latitude to the Railway Administrations themselves.

It is certain that any commercial undertaking should enjoy great liberty of action.

As regards the railway, very little progress has been generally made in this matter. In fact the principles which control railway legislation at the present time are the same as those which were in force when the lines were built; except for certain slight modifications in certain definite cases the fundamental principles have remained unchanged.

In view of the permanent character of the competition between the railway and the other methods of transports, it is only just to arm the two with the same weapons. This does not mean that the railway should be transformed into an industry with complete liberty of action, but that the State control should be of a larger, more flexible, more rapid and more definite character.

The drawbacks of the out-of-date fundamental legislation controlling the railways is more clearly seen in the case of main line railways than on the small lines. If a light railway in competition with a road motor service can resist this competition less successfully than the main railways owing to its smaller facilities, on the other hand, owing to adequate rating measures and to certain concessions, it is in a better position to take action over its whole system.

On the contrary, a main line railway which is obliged to make general all its arrangements, no matter of what kind, can very often find itself obliged to grant concessions or special rates in zones in which motor competition has not made this necessary, and by this fact appreciably affect its receipts. This is the reason why most of the large companies cannot always overcome a local difficulty; in fact as the same conditions can exist in distant areas while recovering some particular traffic in one zone there is a risk of losing other of greater importance elsewhere.

From all these considerations we may deduct the necessity :

1. for the governments to grant to the railway administrations legislation giving them more liberty and one more marked by commercial character;

2. for the administrations to modify their working methods so as not solely to give good service but seriously to take into account the question, which by its very origin has not always been possible, of directing all their efforts in an industrial direction and consequently allowing themselves to be guided essentially by financial principles.

The controlling of road transport undertakings in each country includes most often the same prescriptions as those imposed on railway transport undertakings. Special laws issued in connection with the establishment of these services are in force in Germany, Jugoslavia and Denmark; in Belgium and Holland for passenger services, and in Algeria for the subsidised lines. Of the special legislation introduced with regard to motor transport, that of certain countries deserves special mention.

In *Switzerland* for example, the concession for the lines are granted according to the law on the organisation of the Post Office services, of the 2 October 1924, which in turn is based upon Article 36 of the Constitution.

In consequence the operation of all regular passenger road services requires a concession from the Federal Government regulated according to the law. Curiously enough, cases are reported in which several of these lines have been subsidised by the Post Office Administration in order to cover the working deficits.

In *Switzerland* there are also lines known as « B^1 » or « circular lines », on which all the passengers return to the departure point and others known as « B^2 » or « tourist lines » on which passengers do not return to the departure station.

All these B^1 and B^2 lines as well as special lines known as « A » are subject to the Federal Law on the civil responsibility of railway and steamship undertakings.

The concessionaires of the B^2 lines, i. e. of those on which the passengers do not return to the point of departure and who compete with railway or Post Office lines are subject to a special tax calculated per passenger and per kilometre at

the rate of 2 centimes, and which is paid to the undertaking competed against, either the railway or the Post Office. This is one of the most remarkable features of the Swiss legislation.

This method also applies to Belgium where road motor services competing with the railway are obliged to pay an indemnity to the latter.

The number of touring traffic concessions in Switzerland in 1929 was 104; the number of concessions for circular lines was 280, 40 of which were operated by foreign contractors.

The Swiss Railways are endeavouring to persuade the State that the special tax mentioned above should also be paid by the concessionnaires of circular lines (B^1).

On the other hand, as regards goods transport by carriers there is absolute liberty and the lorry traffic is not under any control. The Railways have drawn the attention of the Swiss Federal Council to the necessity for legislation on this point.

The only relief that the railways benefit on at the present time in this matter is the rather loose interpretation of certain railway regulations, an interpretation which the higher authorities have sanctioned, with the object of limiting the activity of road transport.

In *Germany* the new regulations on road motor transport are among the most restrictive in this matter.

Every regular road motor passenger service from one locality to another is subjected to a licence. This also applies to goods transport carried out for a third party, to distances above 50 km. (31 miles), an exception being made in the case of transport carried out on their own account by industrial undertakings.

All transport services in operation for a given time of a general public character are considered as regular passenger services.

All applications to start a service is submitted to the higher authorities of each state and the question of knowing if the service to be carried out falls or not within the conditions of the special law is decided by the said authorities, after having consulted the administrations of the posts and of the railways, chambers of commerce and industry of the place where the undertaking desiring the concession is seated, and a delegate of the road motor transport organisations recognised by the Minister of Commerce.

The concession for passenger road motor services in the interior of a State is granted by the authorities of the said State.

If the road motor services have to traverse several States they are subject to the approval of the authorities of these States.

In the event of no agreement having been reached at the end of three months, the Minister of Ways and Communications of the Reich decides the matter on the application of one of the States.

A clause to which no exception is allowed consists in not granting any concession without having received full guarantees as to the safety of operation, the financial standing, the capacity of the undertaking and the fact that the service is not of a nature to damage the public interest. Such are considered to be the interests of the German Railways, safeguarded by the Minister of Transport of the Reich who after enquiry is qualified to give final judgment in all cases of litigation.

When a licence is given certain prescriptions are laid down relating to the hours, to the rates, and to the conditions of transport. A deposit or a bond may be required with the object of guaranteeing a normal service.

The rates are made of general application as on the railways and the road motor service undertakings are subject to the control of the authorities who issued the licence. These latter are also

authorised to withdraw the licence should the concessionnaire not carry out any of the obligations laid upon him.

As regards transport undertakings of a general character and which consequently affect the whole of the Reich, the Minister of Communications fixes the rates, taking into account the railway rates, so as not to damage the interests of the latter.

The rates cannot be modified without the authority of the Minister of Communications.

The road motor service undertakings are subject to the fulfilment of formalities similar to those in force on the railways, as regards the obligation of supplying complete returns and information, keeping registers, books, and all kinds of documents similar to those on the railways, which can be examined by the public administration if need be, when it considers this necessary.

The concessionnaires also are obliged to insure themselves with an insurance company against all damages to goods or passengers up to a maximum fixed by law.

In the case of occasional goods and passenger transport services, regulations dealing with the preservation of the roads are in force. A characteristic condition imposed by the law is worthy of mention. It deals with the punishment — up to imprisonment — of those who by premeditation or by negligence work road transport services without authority and those who commit faults or infringements with regard to the regulations.

In the new *Belgian* legislation, the vehicles may be confiscated when infractions of the laws relating to road transport are discovered.

In *Italy*, the legislation on transport by road prescribes as an essential condition the obligation of obtaining for each line, whether for passengers or goods, a State concession, with the noteworthy condition that any line which may compete with the railway cannot obtain a licence.

The rates on all authorised lines have to be submitted to the same formalities of approval as those on the railways.

All the existing road motor lines either operate neutral services or act as feeder services to the railway. It is obvious however that all occasional and private motor transport services acting with unrestricted liberty are always in a position to compete.

In *Rumania* the law of July 1930 has conferred upon the State the monopoly of the organisation and operation of road services under the Ministry of Public Works and Communications, which has alone authority to issue concessions, by public tender, as regards lines including sections of 100 km. (62 miles) by road.

Moreover the legislation in force in most countries generally governs the condition of the rolling stock as well as approving the designs by fixing standards relating to the dimensions, wheel arrangements, weight of vehicles, interior lighting, ability of the driver, and the brakes; sometimes special guarantees to meet civil responsibility in case of accident are insisted upon, as for example in Sweden.

It cannot be definitely stated that there is no legislation relating to taxes and rates although most often the regulations on the subject are very incomplete. In certain countries, *France* for example, the rates are entirely free of control, eight days' notice being sufficient to alter the passenger rates. In *Holland* the provincial authorities are obliged to approve the rates and time tables proposed by the road motor services. In *Poland* the legal provisions only affect the maximum rate which has to be published every 15 days. In *Denmark* the concession is issued subject to the rates proposed in the application for operating the line being observed.

As regards the taxes, and except those

which fall on petrol, the registration of the vehicles and the running licences, there are few countries who apply a real transport tax, and when this is in force it is applied exclusively to passenger transport.

Moreover it must be noticed that the prescriptions which are imposed by the laws applicable to transport undertakings by road are not very stringent and that in many cases they are easily eluded, with the exception obviously of those dealing with the registration of the vehicle and the running licences, which, although less frequently, are not observed in certain cases. The railway is not concerned in this matter, although several railway administrations report to the local authorities cases of obvious infringements that they have observed and sometimes register protests with the public authorities, but without much result. On the other hand in view of the enormous radius of action of this traffic, as well as its lack of standardisation, supervision from this point of view is very difficult.

Although in all countries there are legal requirements solely applicable to the control of road transport concessions, it is as a rule very difficult to see that they are carried out.

The road motor services, thanks to their special characteristics are nearly always able to avoid many of the legal requirements, not only by not paying the taxes imposed, but also by not obeying the regulations on hygiene, for example, which the public, however, esteem and appreciate.

We will mention in this connection the case of very severe competition with a railway in *Spain*, which was obliged to observe a whole series of hygienic precautions when it was a question of carrying slaughtered cattle, measures which are avoided by the road motor lorry. Carrying out these requirements meant for the consignor a financial charge so heavy that he preferred to use the road and pay a higher price than the railway rate.

The advantages offered by the road motor vehicles when it is a question of carrying goods subject to fiscal rights and import duties are of the same kind.

Smuggling is always easier by road than by railway; frequently the road motor vehicles avoid the difficult points by using side roads; obviously the railway cannot do this. On this subject the establishment in Italy of a special police known as the « milicia estradal » (road police) must be specially mentioned.

In *Spain* since 1924, when the Government began to grant exclusive concessions for given routes, the road transport has been brought under special legislation. This has undergone many changes, according to the requirements, either at the request of the railways or of certain provinces with the object of increasing the road transport, in places where the railway system was little developed.

At the present time the Government has decided to call together a transport conference composed of representatives of the State, of the railways, of the road services concessionnaires, and of their users.

The object of the conference is to examine carefully each problem so as not to hurt the development of the road motor vehicle, but at the same time make it possible not to damage the field of action of the railway and to safeguard the economic interests of the country.

Much is expected of this conference, but it is not yet possible to foretell what the results of its deliberations will be.

Methods employed by the railway administrations to defend themselves against road competition.

Passengers.

As regards passenger traffic, attention has principally been concentrated on the

two questions of the rates and the train services.

As regards the rates, special reduced fares have been introduced in various ways so as to make these reductions conditional.

Most of the railways have introduced important reforms from the point of view of modifications in the rates, by issuing return tickets, season tickets, etc. In *Finland* monthly season tickets, valid for three people at once, are issued.

The *Belgian* Railways also grant reduced rates, apart from the summer holiday season, with reduction of as much as 40 % of the ordinary fare for groups of 150 passengers, and as much as 50 % for groups of 400 passengers.

The *German* Railways on the other hand up to the present have not modified their rates for passengers and luggage.

The *Algerian* lines of the Paris-Lyons-Mediterranean Railway are considering the question of introducing a fourth class with reduced rates.

In *France,* for example, family tickets are issued, and also special tickets which allow motor cars to be conveyed by the same trains as the passengers owning them, the traffic being dealt with at certain definite stations.

In the same way, in nearly all the countries covered by our report, there is a parcels service dealing with unaccompanied luggage, which makes it possible to recover at least the conveyance of the luggage of those passengers who travel in their own private cars.

In *Spain,* there is a type of ticket in great favour with the public and which, in fact, is now being investigated by several railway administrations of other countries who think it might be worth while to introduce such tickets on their system : this is the mileage ticket. By buying a book of coupons, each of which is valid for 5 km. (3.1 miles) a given number of persons, members of a family or association, whose names and photographs are entered in the book in question, can travel at will during the time the ticket is valid. The number of persons who can use the book of tickets and the period of validity increase in proportion to the total mileage of the tickets purchased.

As regards the train services, in all countries the speed of the trains has been increased and the timetables adapted to meet the demands of the public; as far as possible, the formalities inherent in booking passengers have been simplified, and the staff instructed to show the utmost courtesy in dealing with the public, so as to give the public the greatest possible travelling facilities within the limits allowed by the regulations of the railway companies. In the same order of ideas has been the experimental introduction of petrol rail motor coaches, or heavy-oil motor rail coaches with electric transmission and Diesel motors driving the generators.

These rail motor coaches are of real value in combating road transport competition. They make it possible to reduce the cost per train-mile considerably, and can be run at speeds up to 70 and 80 km. (43.5, and 50 miles) per hour, and in some cases even above 100 km. (62 miles) per hour; they also make it possible to adapt the service more closely to the requirements of each district as regards more convenient timings, than can be done with ordinary trains.

In *France* several types of rail motor coaches with pneumatic tyres have been tested. The essential characteristics of these vehicles are : quicker accceleration and better braking. In principle this method of working a service appears very attractive, although no definite decision has yet been made; the investigations will be continued and it is proposed to introduce services of this kind on certain of the main French railways as trial services. The secondary railways already use bogie motor vehicles with

steel tyred wheels with accommodation for 80 (power : 100 H. P.) and vehicles with two pairs of wheels for narrow gauge lines, these vehicles taking the place of light passenger trains.

In *Belgium,* the National Light Railway Company has introduced on a line where competition is particularly keen, a rail motor coach service, which at the present time is worked by three vehicles and gives excellent results. The cost price per kilometre has been reduced from 8 fr. (steam) to 3 (rail motor coach); the speed has been increased from 18 to 35 km. (11.2 to 21.7 miles) per hour, and with an hourly service the receipts have increased by 68 %. On the line in question, as on others, Dion-Bouton and Saurer vehicles are used, the characteristics of which are identical. There is seating accommodation for 30 passengers. One type also has a compartment at the rear which can carry up to 1 500 kgr. (3 300 lb.) and which is used as a luggage compartment or for parcels traffic.

The Belgian National Railway Company has organised on certain lines passenger services by means of rail motor coaches, with heavy-oil Diesel motors of the Maybach E.A.V. 100 type, or by steam rail motor coaches of the Sentinel type. This railway company has no rail motor omnibuses in use.

The *Algerian* lines of the Paris-Lyons-Mediterranean Company have in service two Berliet rail motor omnibuses of the Berliet type with 2nd-class and 3rd-class compartments, and luggage and post office compartments. Accommodation is provided for eight 2nd-class and forty-four 3rd-class passengers, with seats for thirty-eight of these; there is also a luggage compartment, a mail compartment, and a driver's compartment; they are electrically lighted and heated by means of the exhaust gases. The motor is a 100 H. P., 6-cylinder Berliet M.L.A. type. Each unit weighs 19 tons.

The *Damas-Hamah* Railways, in *Asia Minor,* have recently organised a rail motor omnibus service on their lines, with Dion-Bouton vehicles. This innovation seems to have been appreciated by the public but is of too recent date for the results to be appreciated.

The *Czechoslovakian* State Railways have introduced rail motor omnibus services on lines with small traffic. Electric transmission has been chosen for these vehicles. Eight-wheeled coaches are used on secondary lines with heavier traffic, as well as on the main lines, in order to make connection with the fast trains which run at less frequent intervals. As these vehicles do not have to make frequent stops and are only used over sections where the motors are not worked very heavily, mechanical transmission has been used; in other cases electric transmission has been used. On the difficult sections of certain lines, it has been proved that motors of less than 200 H. P. are not powerful enough, and that it does not pay to force the motors in view of the large amount of fuel consumed. Tests are being made with Diesel motors from which much is expected as far as a reduction in the working cost is concerned.

Apart from the Railway Administrations mentioned above, who have already made use of stock of this type, many others are considering the matter, but it would appear that the majority are not at present inclined to undertake tests of this sort.

The *North of Spain* Railway Company which has used rail motor coaches on electrified sections of its lines with much success, has just issued enquiries for the acquisition of different rail motor coaches, from the light type to the Diesel-electric type, with the object of getting them into service as soon as possible so as to get the necessary experience in view of a wider extension of this type of vehicle.

Another method employed by the railways to combat competition is the organ-

isation of auxiliary services between the stations and towns situated at some distance from the railway.

In general door to door passenger transport service is very rare. Of all the Administrations consulted, only the *Swiss Federal* and *Czechoslovakian State* Railways have passenger services of this type.

In *France,* auxiliary companies carry out this service by motor, but only in the case of towns some distance from the railway. These services, which might be called correspondence services, are being carefully studied in Poland.

In *Spain* also, for some years there have been correspondence services and at the present time these are being developed as much as possible.

The Spanish Railways have found it difficult to extend these services because of the restrictions of the existing laws, which are, however, going to be modified so as to regulate the road transport services.

In the case of passenger transport generally, in all countries motor services are run in conjunction with the railway to towns at some distance from the latter.

In *Germany,* for example, the railway administration itself operates 12 lines, with a total mileage of 234 km. (145 miles), and in conjunction with the Post Office Administration, 63 lines, with a total mileage of 1 610 km. (1 000 miles). In addition, in conjunction with other organisations, it operates a further 26 lines, with a total mileage of 1 567 km. (974 miles).

In *France,* such services are widely developed. In *Portugal* and *Switzerland* also they exist in great numbers and are operated in conjunction with the Post Office Administration.

Goods.

As regards goods traffic, the measures taken to combat road competition also concern the two following elements :

1. train services;
2. rates.

Train services.

In all countries efforts have been made to establish very fast services for all classes of goods, and in particular for the parcels traffic. At the same time, central despatching services have been established, the receiving and delivering services being contracted out to private firms who deal not only with the service itself but also with the correspondence and reconsignment arrangements. In this way, door to door transport is obtained.

In this connection particular mention must be made of the fact that it is better for the Railway Administrations to associate themselves with local firms in each centre rather than to set up large companies serving a whole group of places. In this event, the carrier should not be content with assuring the conveyance properly speaking, but should also act as the commercial agent of the railway, since no-one, whatever his ability, who is called upon to work in a locality where the people and industry and conditions of life are strange, has the same advantages as a native of the place with his local interests and established connections, which it is always hard for the stranger to work up. This would seem to confirm the method met with in many cases by which the railway administration commissions a large firm, possibly an affiliated company in which it is interested financially, to handle under contract the local services. It appears to us that the railways expose themselves to failure when they try to operate such services directly instead of employing local agents.

The *German State* Railways which have organised such services in this way own 28 lines with a length of 737 km.

(458 miles), which they themselves operate, and 869 km. (540 miles) of lines operated in conjunction with other road motor undertakings.

In this respect it is interesting to mention the case of *Denmark* where of the 400 stations on the railway system, 350 have a door to door goods collection and delivery service.

In *Italy*, the service between the railway stations and customers' premises are carried out by the National Transport Company (I. N. T.) in conjunction with the State Railways.

In *Switzerland* also, such services in conjunction with the S. E. S. A. are very widely extended. The collaboration between the Railway and the Post Office, which has organised many road services, is so close that many of the functions of the one and the other are carried out indiscriminately by the railway or the Post Office staff.

The introduction of road motor services by the Railway Administrations is in our opinion a question that needs very careful preliminary study. In fact it is possible — such a condition of affairs has already been known — that one or other administration, in order to prevent other competing undertakings from carrying out certain given services, increases the number of road services and thereby involves itself in considerable expense, which in principle simply corresponds to competition, with the additional fact against it that it is competing with itself.

Contrariwise, such services are always advisable when it is a question of short journeys, and of services expensive to carry out by rail, where the traffic is small, so that it is best, when possible, to suppress the railway service and to work by road the service between the junction stations and the destination point.

In *Germany*, the railway administration has in certain cases suppressed the service on short lines where there was only passenger traffic, in favour of a road omnibus service operated in conjunction with the Post Office.

In *Belgium*, *Norway* and *Poland*, in the case of certain short distance secondary lines, the railway services have been suppressed in favour of road services carried out by means of an agreement with motor omnibus companies.

In *Italy* also, the railway service on two secondary lines has been suppressed, because of the cost of working it, in favour of motor omnibus services for passengers and luggage. These lines have a mileage of 33 and 26 km. (20.5 and 16 miles) respectively.

The door to door services bring out a very interesting point which merits special study owing to the formalities and the compliance with certain legal requirements which are necessary in the case of all road services worked by the railway, even when these are conceded to a private firm.

In most countries, and amongst others in Spain, when a service is set up between a railway station and the consignee's premises or vice-versa, within the limits of one district, the contract between the railway and the contracting firm, as well as the rates, have to be submitted for approval to the Government inspector.

In all centres of some importance where such services are set up, there are already a number of carriers, who carry out such services between the station and business or other premises, or vice-versa. Competition between the railway and these road carriers is at once set up, and obviously since the activities and initiative of the railway are limited by legal prescriptions, the road carriers are generally the more successful.

Under these conditions the railway company's agent can do but little and there are only two solutions for such a state of affairs : either to charge high rates for the small amount of work he does, and in this event the public will

turn over to the carriers, or else to collect a low charge from customers and supplement this by the railway paying the difference, which subsidies to its agent will frequently result in the railway losing part of the profit it could obtain from the increase in the rates to meet the costs of the door to door service.

Rates.

As far as goods rates are concerned, apart from reductions usually made in order to combat motor competition, which vary according to local conditions and the distances covered, certain Administrations, and among others the French Railways, have introduced special rates for the transport of goods carried in containers, by basing the rates on the net weight of the goods and by granting special facilities for the return of such containers at exceptionnaly low rates.

The use of containers is evidently of great value in certain cases, for example when it is a question of goods easily damaged and which should be handled as little as possible; but it is nevertheless true that a general application of this method would result in many inconveniences and difficulties.

Apart from the fact that the container itself whether loaded or empty, is carried free, and may in this respect, be compared to a covered wagon, this method of carriage means a smaller return from an ordinary wagon, as containers through their capacity or their suitability cannot be used for all classes of goods, nor can they be used when the goods do not conform with the conditions governing the special rates.

On the other hand, the need to be able to handle containers makes it necessary to have special lifting equipment in many stations not yet so equipped, as, although it is easy to handle ordinary parcels by hand, in dealing with « containers » it is necessary to use mechanical appliances.

Should the number of « containers » increase to any great extent within the limits of the total number of wagons, the storing of this auxiliary stock on the banks and the loading and off-loading of the lorry at and from the bank to the wagon would much complicate this kind of transport, the cost of which would increase in consequence. Furthermore it is not always possible to transfer the container directly from the wagon to the lorry or from the lorry to the wagon.

Although some Railway Administrations may have provided in their stations the necessary equipment for this service, on the other hand there are many who do not expect to obtain much benefit by it as, apart from the necessary station equipment, the considerable expenditure needed for the purchase or hire of the containers would largely do away with the profit obtained from the traffic recovered by the use of such stock.

Consequently, in our opinion, this system may be valuable as an auxiliary element in certain cases when it is a question of fragile goods over one definite route, but we do not think that its general application is likely to counterbalance the competition of the road motor services.

Other railway administrations have used and use, in the struggle against such competition, other methods, more particularly in connection with the rates, sometimes as regards the actual charges, and sometimes as regards the conditions.

Thus the *Polish State* Railways despatch registered goods immediately they are handed in and in many cases refrain from applying the supplementary charges for express carriage; they have introduced light trains for parcels traffic which are worked to suit the needs of the trafic, at the same time simplifying the formalities as regards registration and loading, removing certain require-

ments as regards packing, and granting facilities as regards the demands for and the placing of wagons.

The *Danish State* Railways have reduced the minimum of 5 tons for consignments by complete wagon loads to 3 tons when the distance exceeds 125 km. (78 miles).

The *Swiss* Railways, in certain cases when it is a question of a consignment of goods by complete wagon load of a minimum weight of 1 500 kgr. (3 300 lb.), charge in each case the same rates as those charged by the road motor services.

When it is a question of running a competing service, it is necessary to so organise the working as to have the greatest possible adaptability compatible with the legal limitations. In order to combat those agencies which offer « all-in rates » the railways, the rates over which must remain unaltered, must enjoy the necessary latitude as regards the auxiliary services between station and premises at both the loading and unloading points.

The most practical method of assuring this flexibility seems to be that of coming to an agreement with transport agencies already established in each centre, who will work for the railways; this work would consist in propaganda on the part of the said agencies designed to interest the public in making use of them for door to door service. The corollary of this system is the grouping of consignments which can be done by the agencies, and also the granting of progressive allowances on tonnage according to graduated scales.

This system of allowances which has proved efficacious in practice is one of the best methods of meeting the competition of lorries as regards the transport of goods.

The lorry, by reason of its nature, attacks what we might call isolated traffic, i. e. that of small tonnage.

On the other hand when it is a question of traffic of considerable volume to be fully guaranteed as to the regularity of the service, the motor service is unable to deal with it.

In order to deal with such traffic the motor services would have to be organised in a complicated and expensive fashion, and in such a case the railway at once profits by reason of its natural advantages of capacity and real cost of transport, and is undeniably in a better position to deal with it than the motor services.

In order to combat the activities of road transport, the railways are recommended to induce consignors by means of some financial stimulant, to group their goods together, so as to enable the railway to turn these « groupings » into great traffic currents.

In *Spain,* negotiations on this point have been carried through several times with consignors of goods of the same kind, and it was seen that in this way it would be possible to recover important traffic now transported by road, if the State would grant the railway greater latitude than it now has, especially as regards the granting of reductions (allowances) varying according to the tonnage.

As regards this question, there are two kinds of grouping : that of goods of the same kind being sent together by several private individuals; and that of several lots of goods sent by transport agencies.

In both cases the same system of allowances can be applied, though in the second case it is always more complicated than in the first to get out a suitable rate.

Furthermore, in *France,* the hours at which the stations are open have been extended for the benefit of the public; covered-in sheds are reserved for the consignors of « grouped » goods which latter receive especial attention. By this means it is hoped that the public using transport agencies may derive the maximum benefits thereof.

On the *Algerian* lines of the Paris-

Lyons-Mediterranean Railway, allowances are granted on the rates for express « grouped » goods which vary from 10 to 30 % according to the monthly tonnage offered by each contractor.

In *Rumania*, the road motor undertakings are given space in the station for car parks, workshops and offices; « grouped » rates are granted to them for the traffic they bring to the railway, the latter making over to them the goods cartage service in the locality.

In *Germany*, the introduction of uniform rates, applicable over the whole country, for door to door transport, which shall be much lower than those now in force at the large centres and can be again reduced if competition should make it necessary is under consideration; if need be the railway will assist the consignors financially.

It is also proposed to come to an agreement with an important group of express motor services in order to set up door to door transport services by railway and motor jointly with inclusive rates.

When this is done it can be said that, on the railways applying the « grouped » rates, the « all-in » system of rates for door to door transport is really favourable. This is what is being done by the *French* Main Line Railways and by the Railways of *Asia Minor*.

Other railways, such as the *Netherlands* Railways, make use of their affiliated companies who act as the agents of the railway in the case of « all-in » transport.

In *Greece* and *Denmark*, this system of rates is also used, through the intermediary of the concessionnaires of the motor lorry services. In Germany, as has already been said, investigations are being made into a proposal applicable to all the German Railway stations which will make it possible to set up such combinations.

Co-ordination.

The result of the above considerations is that there can never be perfect co-ordination between the railways and motor services.

It is desirable to do away with all difficulties and to encourage all efforts to increase as much as possible the number of cases of co-ordination; this number will increase as the intervention of the State becomes more efficacious, since its intervention should establish proper equilibrium between the legal and financial conditions which have to be observed by the railway and those the motor services must work to.

All correspondence and reconsignment services are co-ordinated services; but when it is a question of dealing with such questions with the concessionnaires of road transport undertakings, it has been observed that these latter all desire to extend such co-ordination to the services we call « parallel » and the co-ordination particularly stressed by them is always that which enables them to work on the basis of mutual concessions which generally complete those under which the railways favor co-ordination.

The result is that many of the agreements between the railway administrations and road transport services end by making a sort of traffic syndicate, and it is obvious that as the railway itself can assure the whole of the service, the fact of coming to an agreement with its competitor does not bring it any direct advantage and can only serve as a sort of safety premium to prevent greater competition.

In *Germany*, for example, since June 1929 there has been an arrangement between the Railways and the Post Office Administration, according to which the transport of passengers on the road over lines already in existence at that date remains exclusively in the hands of the latter. The railways can share in the working of motor lines established after

this agreement was made, but as far as lines thought to be competitive by reason of the route covered are concerned, the railways can fix the route, timetable and rates; participation in the profits or losses, to the extent of 65 % or 35 % according to whether the lines are or are not competitive has been arranged.

In *Belgium,* the question of entering into agreements with competitive motor omnibus companies is being considered. It is suggested that these lines become the property of the railway which applies the same rates as those in force on its own system. The total receipts will be handed over to the railway who will pay the road undertaking 3.50 fr. per loaded vehicle-kilometre, plus 5 % of the gross receipts.

The motor transport companies will have to supply the stock and staff.

In *France,* the undertakings working in agreement with the railway have to apply the rates and work to the timetable approved by this latter; they have to comply with certain regulations as regards the stock and the insurances against accident. In return they often benefit by financial guarantees given by the railway company.

The *Algerian lines* of the Paris-Lyons-Mediterranean Railway intend to make agreements with such road transport undertakings as undertake not to compete with the railway, by letting them share in the revenues obtained by the railway as the result of such an agreement.

The *Morocco* Railways grant a premium to motor undertakings on the tonnage of traffic they bring to the railway.

In *Holland,* the railway has in some particular cases subsidised feeder omnibus services.

In *Czechoslovakia,* the railways share financially in a road motor transport company.

In *Switzerland,* the railways have no direct agreements with the consignors but act through the intermediary of the S. E. S. A.

This undertaking, which owns no vehicles, makes contracts with the owners of vehicles who engage not to compete with the railways.

As regards combined rates, up to the present time few railways have introduced combined rates with road transport undertakings. Several railways apply these rates to some combined correspondence and reconsignment services; but in both these cases the total transport cost is made up of the sum of the two rates of the two methods of transport.

In *France,* special through tickets with a reduction of 50 % on the usual fare have been introduced for journeys made partly by rail and partly by road.

In *Holland,* there is a combined scale of rates, the basic railway rate being applied over the whole distance; the amount is so divided up that each party receives half the fixed charges; as to the variable part of the charges, this is divided up according to the distance in each case.

In *Sweden,* where combined rates for certain services worked in common are also in force, the price as a rule represents the sum of the two rates; but in some cases a reduction is granted on the whole amount.

In those cases where there is an agreement between the railway and the motor road undertaking for combined services, the responsibilities are divided up as follows : as regards those which in general relate to the railway journey, the laws concerning the working of the railway are applied; as regards the journey by road, the general civil and commercial laws of each country are applied.

In *Holland,* the responsibility as regards combined goods transport services (the only combined service in existence) is determined according to the previsions of the Berne Convention.

In *Greece,* the railways take all responsibility towards the public, with the reserve that they themselves hold the

road motor undertakings to their share of the responsibility.

Here again, as in the case of many of the other questions considered above, the difference between the way the railway and the road services are treated is manifest. In fact, the railway can never escape its obligations, not even those which cannot fairly be attributed to it; the road motor service on the other hand, except when it is a question of an important and properly organised undertaking, is not subject to so many restrictions and often endeavours to lessen and even avoid its responsibility altogether under the pretext of the insolvency of its owners or the drivers concerned.

Conclusions.

1. — The competition of the road motor services with the railways is on the increase and is more especially met in the case of passenger traffic than of goods traffic.

2. — Although most Governments have considered the question of introducing special laws, those promulgated up to the present have not been sufficient to establish a just equilibrium between the legal conditions imposed on the two methods of transport.

Consequently it is necessary to insist that the public authorities bring the road transport services under laws similar to those governing the railways, and set up an organisation responsible for the supervision of the roads, which shall be responsible for controlling the way the regulations are carried out. Moreover, in principle the setting up of all regular motor services should be dependent upon the obtaining of a special licence which should only be granted after preliminary investigation into the opinion of the railway administrations likely to be vitally affected by the existence of the line in question.

With this object in view it is desirable that a Transport Council be established for granting such licences after an enquiry into each particular case.

This Council should in principle include representatives of the State, the Railway Administrations, Road Motor Companies, and also of the Public using these methods of transport.

An endeavour should be made to assure the equality of the taxes carried by each method of transport, and when a concession is granted the conditions imposed should vary according to whether it is a question of neutral services, services acting as feeder lines to the railway, or services competing with the railway.

In the same way we consider it desirable for the Governments to grant the railways, while retaining the present system of inspection and guarantees applicable to a public service, the necessary latitude in regulating their services, so that they can reduce their operating costs and, when it is a question of rates, adapt these to the needs of each particular case, by acting rapidly, in a commercial way, with the object of retaining their traffic and even recovering that lost for one reason or another.

3. — Notwithstanding governmental intervention, there is always inevitably more or less serious competition, according to the degree of protection the Government gives the railways. It is to be recommended that the direct action of the railway administrations should begin at the point at which the State influence ends, and that this direct action consist in seeking for all possible means of co-ordination with the road transport undertakings. At the same time each particular case should be examined very carefully, so as to avoid or at least lessen the grave danger of such co-ordination resulting in the railway paying a subsidy equal to — if not greater than — the value of the very competition it is desired to avoid.

4. — Furthermore it is necessary to modify, by improving them, the operating methods. For this it is to be recommended that recourse be had more and more to the use of fast light rail motor coaches. The introduction of special fares for passenger services and rates for door to door services should be extended as much as possible, by making use preferably of accredited transport agencies. It is also profitable to extend the grouping of consignments of goods, as well as the system of granting allowances for certain minimum tonnages. The use of containers can be recommended in certain definite cases, but in our opinion they can only be considered as a partial solution in face of the amount of traffic susceptible of loss to the road.

II. — Railways and airways.

1. The question of the competition between railway and airway presents very different characteristics according to the country of the different railway administrations consulted. In Switzerland for example, in view of the topographical conditions of the country and the short distances, the development of air services is not likely to have any great effect on the railway. On the contrary certain international air services via Switzerland make use of the transalpine railways over certain sections, and consequently it is possible that the development of travel by air may in this case be advantageous to the railways of this country. In *Poland* there is very useful collaboration between the railway and air services.

Consequently the present development of the air services is not very harmful to the railways, though certain *French* Railways, for example, mention the case of the air service between Paris and Amsterdam on which the Farman and K.L.M. lines carried 400 tons of mail during 1930, obviously at the expense of the railway.

From the point of view of passenger traffic, the German railways mention a loss in receipts chiefly as regards the luxury classes, due to air competition. In *Denmark* the air services are greatly favoured by commercial travellers.

The transport of mails would seem to be best covered by the air services. In view of the special conditions, however, by which the railways of most countries are obliged by law or the terms of their concession or agreements with the different Governments to assure the postal services, this competition does not seem to be very severe and there are few or no means of avoiding it.

The *German State* Railways mention that in 1929, 300 tons of letters and parcels were carried by air.

As regards goods traffic, commercial aviation is only in its initial stages, and the railways the most affected thereby are not yet in a position to estimate the degree of harm this competition may do to them. As an example the *Netherlands* Railways have observed a real decrease in certain export traffic, particularly in the export of cut flowers.

Other concrete examples are given by the French Railways as regards the transport of gold between England and Paris, and the import of laces from Belgium.

In general the classes of goods most affected are naturally those which weigh the least, or goods of high value, or those which require particularly fast transport. Consequently these goods do not represent any great tonnage, but on the other hand are those which are rated the highest on the railways and can therefore have an appreciable effect on the receipts.

As regards the transport of goods, particular notice should be taken of the fact that the night air services are still few and far between, and when it is a question of transport over great distances certain airway undertakings prefer to make use of the railway during the night and pick up the goods in question again the

following morning, avoiding in this way a night flight of 600 to 800 km. (370 to 500 miles) with the load in question.

Certain air services have organised their services in this way. For traffic carried in this way lower rates are in force than would be the case if carried by air over the whole distance, but they are always higher than the highest railway rates.

This leads the air services to make use of the fastet trains, and, thanks to the lower railway rates, enables them to make up for the lower rate they themselves charge for the total distance.

In general it can be said that the most suitable traffic for airways is that of the mail because the rates are very high in comparison to the weight.

There is no other class of goods capable of supporting, either from the point of view of weight or volume, the rates applied to the transport of postal packages.

Most commercially organised, air services take the postal traffic as their base and there are also cases in which from the technical point of view the conditions laid down for the postal traffic do not fit in with the requirements of goods and passengers traffic.

The machines used for the mail services are light, rapid and economical; passenger planes are heavy, slower and very expensive. Planes for goods services need to have a much greater capacity than that of the mail planes.

2. — In most cases when air services are in competition with the railway, the reason why the air services are preferred is one of speed; in some cases it is cheaper to travel by air than by railway in the luxury classes.

In *Germany*, the rates of some of the air lines are based more or less on those of the railway, but in most cases they are appreciably higher.

In *Belgium*, the only advantage seems to be the greater speed; the fares are always higher than by rail. Between Paris and Brussels for example the journey by air takes less than two hours, while the express trains takes three and a half hours. It costs 350 francs to go by air, while the first class railway ticket is under 300 francs.

In *France*, this competition is found under different aspects especially from the point of view of the rates. In fact, for certain journeys it is cheaper by air than by rail. On the London to Paris service, for example, a return ticket costs 600 francs; a first class ticket by rail and steamer is 725 francs via Calais and 674 via Boulogne.

In *Holland* also, there is competition from the point of view of the rates in favour of the air services. It costs 48 florins to go from London to Amsterdam by air; by train and steamer it costs 40.40 florins, excluding the supplement for sleeping-car, saloon-car, restaurant-car, etc... The journey takes 2 1/2 hours by air and nearly 12 hours by railway (steam traction).

In *Poland*, the air services profit solely because of their greater speed, the distance being more or less the same for both methods of transport. For example the distance between Warsaw and Poznan is 285 km. (177 miles) by air and is covered in 2 hours 10 minutes, while the distance by rail is 304 km. (189 miles) and the express trains take about 5 hours.

In *Switzerland*, the advantage of air travel taking a shorter time is lost to some extent by the time lost at the aerodrome, as well as the short distances of the air routes in the country itself. The air rates, though relatively cheap, as they are not much higher than 2nd class railway tickets, do not make up for this drawback.

In *Czechoslovakia*, the rates for passenger air services are the same as 1st class fares by express trains. The competition is therefore only helped by the greater speed of the air services.

In *Jugoslavia*, the air rates are so high

that the danger of competition is appreciably lessened in spite of the enormous advantage as regards speed. Thus the distance between Belgrade and Zagreb which is 435 km. (270 miles) is covered by air in 2 1/2 hours while the express trains take about 9 hours.

3. — The measures taken up to the present to combat air competition are few in number in view of the fact that the railways have not yet paid much attention to this question.

The *German* Railways, however, who have begun to feel the effects of this competition for distances of less than 300 km. (186 miles) — which already represents a real disadvantage for the railway — have occupied themselves with the question of conserving passenger and goods traffic which might be taken from them by the air services in this way, and with this object have come to an agreement with the « Deutsche Luft Hansa » for the establishment of joint services, which, though they may seem in some way to benefit even more the air traffic, on the other hand assure to the railway its own particular short distance traffic which otherwise might be lost to the completing road services.

In *France* also, part of the traffic lost is being regained, but it must be admitted that the measures taken are ineffective in view of the fact that the air transport services are able to change their rates without warning, while the railway has to comply with the legal restrictions in force in this matter.

4. — No special authorisation is necessary to enable the railways to run air services, with the obvious exception of the legal prescriptions regarding alterations in the rates.

The fundamental reason is that since the War the transcendent importance of aircraft from the military point of view, since they cannot be produced suddenly, has been sufficiently proved. Consequently most countries have not only to subsidise aeroplane builders, but also to look for new improvements and betterments in practical aviation. In fact it may be said that up to the present the commercial utilisation of aircraft seems to have been considered from this point of view rather than from that of a transport undertaking.

5-6. — In *Germany*, the agreement with the « Luft Hansa » was made the 1 September 1928 and still applies to passengers and luggage, under a slightly modified form; at the present time a proposal is being investigated which takes into account the standards imposed in agreement with the International Railway Union. There is a similar agreement with the « Luft Hansa » for goods traffic.

In *Belgium*, there is an agreement as regards goods traffic between the Belgian railways and the S. A. B. E. N. A. (the only Belgian undertaking organised for air transport) the clauses of which are more like those relating to contract services than those of the combined services between different railways. There is no agreement in the case of passenger services.

In *Denmark*, there is an agreement of this kind for issuing tickets between Copenhagen and Malmoe to passengers who go by air and return by railway or vice-versa.

In *France*, combined rail and air rates are being considered.

In *Holland*, though there are no agreements for combined services certain stations accept consignments for reconsignment by air from Amsterdam and Rotterdam, forwarding them in this case by fast trains in correspondence with the timetables of the air services.

In *Sweden*, there are contracts for combined traffic in the case of parcels and express consignments which are accepted at certain stations for carriage to Berlin, Hamburg, Vienna, Amsterdam, Paris and London, on the basis of joint transport contracts, the responsibility as

regards carriage effected by railway being fixed in agreement with the decisions of the Berne Convention.

In *Switzerland* an agreement has been made with the « Swiss Air Company » for combined traffic between the air service and the railway, as regards the transport of goods; but up to the present it has not been made use of.

7. — It goes without saying that the greater part of the goods traffic of the air services has been taken away from the railway, although it cannot be denied that the railway has also profited by some increase in traffic thanks to this evolution; in the case of passenger traffic, the air service takes away from the railway its richest customers, those who consequently pay the highest rates. This is the general opinion of the railway administrations who replied to our questionnaire, with the exception of the Belgian, Swedish and Swiss railways, who state that at present the air services can be considered as collaborators with the railway, to which thanks to such services they bring new traffic.

The *German* Railways state that the « Luft Hansa » recruits passengers among students, for example, in order to fill up vacant places in its machines, carrying them at rates equal to those of 3rd-class express train tickets, and they add that it can be definitely stated that those who now travel by air formerly travelled by railway.

8. — Although, from the point of view of comfort of the passengers much progress has been made recently, by equiping the aircraft with closed cabins, comfortable seats, and even heating them, in this field they still cannot be compared with the railway, above all because of the limited amount of space available. Furthermore the restaurant and sleeping-car services now found on most modern trains are still lacking on most machines, except in the « de luxe » planes. And even these cannot compete with the great European expresses from the point of view of comfort.

9. — There is a night air service for the transport of mails between *Brussels and London*, and also in *Sweden;* the question of introducing such a service is being studied in *France, Switzerland*, and *Czechoslovakia.* In *Germany*, there are already night services over 4 routes for passengers, a total of 1 400 km. (870 miles) and over 2 routes for goods. These services will be extended with the introduction of light signalling for marking the way.

10. — At the present time, the air transport services are not in a position to support themselves. They exist thanks to official aid which is given under various forms: subsidies, safety installations, signals, meteorological services, organisation of air ports, and in general auxiliary services of all kinds. Furthermore, account must be taken of the rents paid to the owners of the land occupied by the aerodromes and installations.

In some countries, not only are the air undertakings allowed to use the military aerodromes and aviation services, but they are also given subsidies in kind. Furthermore, in Germany the State supports an Aviator Pilot School and assists the factories making equipment and motors, by setting aside large sums of money for scientific and mechanical experiments in connection with aviation.

11. — *a*) In all countries connected with the Railway Administrations consulted by us, there is adequate legislation as regards the setting up of air services for commercial purposes. As a general rule, it cannot be said that there is absolute freedom as regards the working of such services, nor that there is a monopoly, as in Belgium for example where it is in the hands of the S. A. B. E. N. A. of which the State is a shareholder.

In the conditions laid down by the Swiss legislation for the concession of

lines there is a tendency to favour the national undertakings, without however excluding foreign enterprises, especially when it is a case of international lines, with the exception of cases where no reciprocal treatment is granted by the owning country.

In *Poland*, the concession can be given to any national undertaking which gives sufficient guarantees for the proper working of the service and the safety of the passengers.

In *Germany*, the law on air traffic of the 1 August 1922 uniformly regulated this traffic over the whole of the country. The decree of the 19 July 1930 laid down certain additional requirements, and authorised the railways to include in their rates the participation of the air services. Undertakings devoted to air transport must first of all be authorised by the Government of each country concerned if their activities extend beyond the Reich, otherwise the authorisation of the German Government suffices. The Ministry of Communications has granted more than 50 such authorisations though at the present time there are only 3 important accredited air service undertakings.

b) Mail carried by air is in all cases charged for at a higher rate than the ordinary mail. This additional tax varies according to the country of destination and in most cases is calculated on the weight of the letters and parcels.

The night service *between Brussels and London* carries mail without extra charge. In *Sweden*, a supplement of 0.10 Swedish crown is charged for every 20 grammes (0.7 ounce) or fraction thereof, on letters carried by air to any European country, but according to the information given by the railways of this country, this traffic is carried by air even when the additional tax is not paid.

In *Belgium*, the S. A. B. E. N. A. has the monopoly of the air mail; we have not however been informed of other similar agreements between the State and air transport services in other countries.

In *Spain*, the first commercial lines connecting the capital to other important centres at an average of 500 km. (310 miles) from it, were set up by a company to which the State granted the monopoly of the subsidy.

No air services can be set up without a preliminary concession from the State, but as a rule the State only subsidises the accredited line, so that practically speaking there can be no other lines than those subsidised.

At the present time, the regulations concerning such concessions have been slightly modified in the sense that the services are carried out on behalf of the State and depend upon legislation which seems to turn in the direction of requiring such services, as concessions of the State, to be made over to private companies, i. e., leased out.

The subsidised air services made some return in the case of passenger transport for a time; the goods traffic remains small.

12. — There are contracts for combined railway and air services in *Germany*, *Belgium*, and *Switzerland*.

In *France*, such contracts are still under investigation. In *Switzerland* the agreements made between the railway companies and the air service company provides for direct consignments to be made between any railway station and any Swiss aerodrome.

In *Germany*, the railways apply rates which are added to those of the air services.

In *Belgium*, the express parcels rates increased by 25 % are applied on the railway, and the air service has its own rates. In *Sweden* the rates are independent and the service conditions are those in force in each case.

In *France*, where, as we mentioned above, the contracts are still under consideration, there are nonetheless certain correspondence services, such as the Pa-

ris to Toulouse, and Toulouse to Casablanca routes. Moreover, in Paris it is possible to buy at the same time as a railway ticket to Strasburg a correspondence air ticket making it possible to continue the journey by air to Prague, Warsaw, Vienna, Budapest, Bucarest, Sofia, or Istanbul.

13. — In *Germany*, the « Deutsche Luft Hansa » Company is responsible for claims lodged in respect of error, damage, and delays, the railway sharing in this responsibility to the extent laid down in the conditions governing the transport. If the railway is in the wrong it must reimburse to the said company the amount of the claim; in undetermined causes or those attributed to both methods of transport, the amount is divided up according to the distance in kilometres. This procedure is also followed as the result of a judgment in the law courts, or after a legal decision which the railway had previously agreed to accept.

In *Belgium* the responsibility of the railway as regards the transport of goods over its system is laid down by the law of the 25 August 1891.

In the case of air transport, however, no claim can be lodged in case of loss, damage, or delay, unless the interested part previously insured his consignment against loss or damage (never against delay) by paying the air transport company a premium independently of the transport rate.

In *Poland* the responsibility is limited to 20 000 Zl. per person, and 200 Zl. per consignment of goods.

In *Switzerland*, the railways refuse all responsibility towards the public, as they only carry out the transport on behalf of the air company. As a result the responsibility of the air company which is even heavier than that of the railway covers the whole journey. Cases of « force majeure » or the faults of third parties do not thereby exclude all responsibility.

14. — Agreements made between the railways and air transport undertakings which relate to the continuation of the interrupted journey, if the air service breaks down, are in force in the following countries.

In *Germany*, the passengers are allowed to continue their journey by rail without charge in the case of services coming under the agreements made with the « Deutsche Luft Hansa ».

In *Belgium*, there is an agreement between the railways and the S.A.B.E.N.A., by virtue of which passengers forced to leave the aeroplane before the end of their journey can choose between continuing by rail first-class, without having to get a ticket (this being paid for afterwards by the air company to the railway) or being reimbursed the amount of the air ticket for the unused distance.

In *France*, the Nord Railway Company has made agreements of this kind with the two companies working the air service between Paris and London, so that in case of forced landing the pilot can draw up an order upon the nearest railway station to issue railway tickets to the passengers (afterwards paid for by the air company) and can ask for a train to be stopped at the nearest point, even when there is no regular stop there, to pick up passengers from the aeroplane.

The French Est and Paris-Lyons-Mediterranean Companies have similar agreements with other air transport companies serving the lines between Paris and Strasburg, Paris and Sarrebruck, Paris, Lyons and Marseilles, and Lyons and Geneva.

The French State has adopted the same procedure in the case of the air services between Paris and Havre, and Paris and Cherbourg. No agreement of this kind has however been made with the « Aéropostale » Company.

In *Switzerland*, an agreement of this kind is about to be made with the « Swiss Air » Company.

In *Sweden* also, there are legal agree-

ments with the Swedish Air Transport Company in conformity with the regulations of the International Railway Union.

In *Poland,* passengers are authorised to continue their journey by rail at the expense of the air service. The pilot is obliged to put them into communication with the railway and refund them the cost of their tickets.

15. — The luggage of passengers travelling by air can be carried by rail in nearly every country at unaccompanied luggage rates. In *Holland,* this traffic is handled under special conditions, the rates being three times those applicable to unaccompanied luggage. In *France* there is in addition a special express rate 100 bis on the Midi-Orleans Railway, which governs the conditions under which consignments for the air services from Toulouse are carried by express train between Paris and Toulouse.

16. — There is a combined air and rail service for carrying the mails in *Poland,* and in *Sweden,* under the control of the Post Office, and in *Czechoslovakia,* in cases where there is no direct air service and with the reservation that the establishment of such combined services is beneficial to the railway.

In *Switzerland* the Post Office administration which holds a monopoly for carrying the mails, has not introduced as regards the international traffic a combined air and rail service for letters which have not paid the air service additional tax. On the other hand, the ordinary mail goes by air so as to use to the full extent the capacity of the flying machines.

17. — To our question if the railway in certain cases acted as agent for the air services, we received the following replies :

In *Germany,* it cannot be said that the railway acts as an agent for the air services in order to obtain traffic. Collaboration between the one and the other only exists in order to assure the continuation by railway in case of interruption in the service by air.

In the case of combined goods traffic, the public makes its agreement with the air company and the railway only acts as an intermediary in order to carry out the transport over a given route not served by the air lines.

In *Belgium* up to the present the following measures have been found sufficient : publication of the timetables of the air services in the railway guides, as well as their advertisements; information given at stations as to the facilities granted by the passenger air services of the S. A. B. E. N. A., and issue of air tickets on request, this latter being done free of charge.

In *Sweden* the railways act as agents for the air services through their tourist agency offices.

18. — As regards goods rates applied to air transport, no case has been reported in which such rates are based on the nature of the goods. The weight of the consignment and the distance alone are taken into account, and it is not even possible to establish any relationship between the bases adopted by the different lines, as these belong to different countries and have very little in common.

In most cases special rates are applied for the transport of very bulky goods of great value, livestock, etc.

In *France,* there are also special rates for consignments of goods in large quantities and consignments of cut flowers, and likewise in Sweden for the transport of fruit, vegetables, and cut flowers.

In *Poland,* the rates for carrying luggage and goods are calculated on 1 % of the amount of the ticket per kilogramme of weight. Exceptionally, in Greece, a uniform base of 6 drachmes per kgr. of weight is applied, except in the case of goods whose bulk is disproportionate to their weight, which are taxed at the rate of 6 drachmes per cubic decimetre.

Conclusions.

1. — In its present stage of development the competition of air transport does not appear to be very harmful to the railway.

As a rule the air services depend to a large extent on the subsidies granted them by the Governments.

2. — The existence of commercial air services would seem to correspond rather to the needs and convenience of the State — which supports this industry in order to assist in its development — than to the building up of a real element of public utility from the point of view of transport within each country.

3. — The introduction of air services would appear to be of use particularly in the case of international traffic and so long as it is over long distances. In addition for there to be any great development under these conditions the machines, landing stages, and signalling must be much improved, so as to make it possible to have night services. Unless this is done it will always be more convenient for business men travelling by night, who wish to save time, to make use of the express trains with comfortable sleeping cars than to break the journey so as to be able to continue it by air the next day.

[621 .135 (.01, 625 .14 (01 & 625 .22]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

XII[th] SESSION (CAIRO, 1933).

QUESTION III:

The relationship between the vehicle and the track to ensure safety at high speeds.

A. Weight of vehicles per axle, position of the centre of gravity, wheel arrangement, layout to facilitate running through curves.

B. Track resistance, widening of gauge, radius of curves, superelevation, transition curves, points and crossings, check rails.

REPORT No. 2

(All countries except America, Great Britain, Dominions and Colonies, China, Japan, Germany, Denmark, Finland, Norway, Spain, Netherlands, Portugal and their Colonies; Sweden and Switzerland),

by Dr.-Ing. Hynek DEYL,

Conseiller ministériel et chef du département IV/5 au Ministère des Chemins de fer de Tchécoslovaquie; Prague.

The question dealt with in this report is one which by its character comes within the practice and study of the civil and mechanical engineers. The long evolution of railways has led to the introduction into the construction of the railways and the rolling stock of admirable improvements in each department separately. The increasing demands of the operating department both as regards speeds and axle loads have made necessary a deeper knowledge and closer observation of the forces and of their actions, so as to improve the construction and to make railway travel still safer. It is remarkable that the action, distribution, and transference of the forces at the points of contact of the vehicles with the track have remained so long and still remain to a large extent hidden and unexplored. The cause probably resides in the excessive specialisation between the different technical services and the lack of sufficiently close collaboration, especially when it is a question of high running speeds. Now it is precisely on high speeds as well as on their ability to carry heavy loads that the future existence of railways depends. The fact that the International Railway Congress Association has drawn attention to the question should therefore be received with satisfaction.

The relation between the wheel and the rail has ben discussed very frequently with interest in the technical

press throughout the world; nonetheless many uncertain points in the different problems that arise still remain without explanation. The field covered by the question dealt with in the present report is too vast for it to be possible to deal with it fully in a limited space and time. We have however endeavoured to develop as fully as possible the various points in our questionnaire.

In spite of the short time allowed them many Administrations have sent in their replies with the necessary technical documents. We take this opportunity of thanking them. Unfortunately it is not possible to reproduce in extenso the whole of the information sent in, and we have had to limit ourselves to making brief references thereto.

* * *

The question has been divided into two parts :

First part : The vehicle;
Second part : The track.

The Ministry of Railways of the Czechoslovakian Republic has allowed me to act as reporter on this question. I found it necessary however to divide the work. I have dealt with the second part : *Track*, whereas the first part : *The Vehicle*, has been written with the assistance of an engineer in the Locomotive Running Department, Mr. R. Fasse, Ministerial Councillor and head of department V/3 at the Ministry of Railways at Prague.

Part I : THE VEHICLE.

The present report includes the information supplied by the different Railway Administrations about rolling stock for speeds of not less than 90 km. (56 miles) per hour. This speed should be considered as the lower limit, speeds in excess of this limit being already considered as high.

I. — General construction and running gear.

What designs of rolling stock (locomotives, tenders, motor coaches, and passenger carriages) do you use for high speeds ?

From the replies received it appears that, four, six and eight-coupled locomotives are used, the first dating from earlier periods than the present, when the work required from the locomotives was not so great (trains were formerly not so heavy as they now are). The six-coupled locomotives are the most usual; eight-coupled locomotives are already in use however, especially for hauling the heaviest express trains and to get high acceleration when starting.

With few exceptions the steam locomotives have one *bogie* with two pairs of carrying wheels of equal diameter. On some Italian locomotives the first carrying axle is connected to the first coupled axle to form a *bogie on the « Italian » system.* For the most recent design of locomotive for a speed of 130 km. (81 miles) per hour (I 691), the usual type of bogie has again been used as this makes it possible to run easily through the curves and at the same time reduces the lateral thrust of the wheels.

A pair of carrying wheels at the trailing end is used when the weight of the locomotive and the maximum allowable axle load make it necessary. These wheels are divided up almost equally into wheels with side movement and bissel trucks, these latter being used especially in the case of the most recent locomotives.

In the countries dealt with in the present report the different cylinder arrangements used are as follows : four-cylinder compound locomotives are used exclusively on the French State, Alsace-Lorraine, Est, Nord, Paris-Lyons and Mediterranean (including the Algerian lines) Railways; on the other French

Railways, they are in a majority on the Paris-Orleans and about half the stock on the Midi. The Italian locomotives are equally divided between simple and compound engines (mostly four cylinders), whereas in Belgium simple expansion predominates (two and four cylinders). Simple expansion engines are used in Egypt, Jugoslavia and Poland alone (two cylinders), in Rumania with two and four cylinders, and in Czechoslovakia with three cylinders.

The part played here by the coupled wheels is shown in the following table :

Number of pairs of coupled wheels.	Wheel arrangement.	Simple expansion in 2 cylinders.	Simple expansion in 3 cylinders.	Simple expansion in 4 cylinders.	4-cylinder compound locomotives.
2	4-4-0	4	...	...	...
	4-4-2	1	...	...	4
3	2 6 0	1	...	...	...
	2-6-2	...	...	1	...
	4-6-0	5	...	1	6
	4-6 2	3	1	3	10
4	2-8-2	...	...	...	...
	4-8-0	1	...	...	1
	4-8-2	1	...	...	...
		16	1	5	22
		22			

The *tenders* have three or four pairs of wheels, either carried in two bogies or rigid.

The water and coal capacity differs considerably: in the six-wheeled tenders, 12 to 25 m³ (425 to 880 cubic feet) of water and 4 to 8 tons of coal are carried; in the eight-wheeled tenders 20.8 to 37 m³ (735 to 1 305 cubic feet) of water (French Nord) and 6 to 14.5 tons of coal (Czechoslovakia). The *total wheel base* in the case of the six-wheeled tenders is between 3 200 and 6 500 mm. (10 ft. 6 in. and 21 ft. 4 in.) (Italy: water tank wagon) and the diameter of the wheels varies between 1 095 and 1 230 mm. (3 ft. 7 1/8 in. and 4 ft. 7/16 in.); for the eight-wheeled tenders, the *distance between the bogie centres* is 4 750 to 6 550 mm. (15 ft. 7 in. to 21 ft. 6 in.); in the case of rigid wheel base tenders, the largest distance is 4 110 to 4 572 mm. (13 ft. 5 13/16 in. to 15 feet) respectively; the diameter of the wheels varies between 920 and 1 247 mm. (3 ft. 6 1/4 in. and 4 ft. 5/64 in.). The *bogie wheel base* varies from 1 800 to 2 300 mm. (5 ft. 11 in. and 7 ft. 9/16 in.), so that the total wheel base of the bogie tenders varies between 5 400 and 6 550 mm. (17 ft. 8 9/16 in. and 21 ft. 6 in.).

The distance between centres of the two leading pairs of wheels of six-wheeled tenders is usually greater [1 750 to 2 800 mm. (5 ft. 9 in. to 9 ft. 2 1/4 in.)] than that of the two trailing pairs of wheels [1 250 to 1 900 mm. (4 ft. 3/16 in. to 6 ft. 2 25/32 in.)].

When these dimensions are the same, they vary between 1 700 and 3 250 mm. (5 ft. 7 in. and 10 ft. 8 in.) (Italy : water tank wagon).

The weight per axle on the tenders begins on small capacity tenders with 10.1 t. (10 Engl. tons) [Paris-Orleans 12 m³ (882 cubic feet)] and rises to 19.25 t. (19 Engl. tons) for large tenders (Nord 35.101). Whereas for eight-wheeled tenders, the individual axle loads are approximately the same, they vary considerably in the case of six-wheeled tenders; the load on the leading pair of wheels especially is either heavier and on the two trailing pairs of wheels connected by the equaliser lever are lighter (Midi, Paris-Orleans) or the opposite way round (Paris-Lyons-Mediterranean).

The *total weight in working order* of the tenders is from 31.2 to 76.9 t. (31.7 to 75.6 Engl. tons).

The Rumanian State Railways have not had favourable results with eight-wheeled rigid-base tenders, as they frequently came off the road.

The *electric locomotives* on railways using electric traction (Midi, Paris-Orleans, Italy, French State) are shown in table I. (1)

They can be divided according to the *wheel arrangement* into three main groups :

1) locomotives with two motor bogies each with two pairs of wheels;

2) locomotives with the driving wheels in the main frame, and carrying bogies;

3) locomotives with two motor trucks which in addition to the rigid driving wheels in the truck frames have carrying bogies.

The locomotives of the *first group* are used generally for speeds of 95 km. (59 miles) per hour; some Administrations report that the bogies have to be connected together elastically if they are to run *smoothly*. On the other hand the French State Railways' locomotor E runs with Pennsylvania type bogies at speeds up to 110 km. (68 miles) per hour. Locomotives of the *second group have* three or four pairs of driving wheels in the frame, and their speed is as high as 130 km. (81 miles) per hour; the locomotives of the last type have six pairs of driving wheels (three pairs in each motor truck) for speeds up to 105 km. (65 miles) per hour. It must be mentioned however that the Paris-Orleans locomotive E 601 worked in an entirely satisfactory manner in ordinary traffic up to a speed of 100 km. (62 miles) per hour; for higher speeds [over 110 km. (68 miles) per hour] considerable hunting of the trucks was noticed, so that it would seem that this figure is the limit with electric locomotives with articulated frames.

The method of driving the locomotives is as follows :

1. One or two motors driving each pair of wheels independently (Paris-Orleans E 501, 601 — French State BB 1, 101, 225 — Paris Lyons-Mediterranean 252 — Alsace Lorraine E — Italian State, E 326 — French State, locomotor);

2. Two motors driving one pair of wheels by triangulated rods and the other pairs of wheels by coupling rods (Paris-Orleans, 401 — Italian State, E 330, 431);

3. Quill and connecting rod drive (Italian State E 332).

The Administrations who have given details of the methods of transmission used on their locomotives with independently driven wheels, use either the Büchli or the Oerlikon transmission systems or spring supported motors of the tramway type.

The construction of the four-wheeled bogies does not differ from that of bogies used on steam locomotives; the French State locomotor E uses Pennsylvania bogies. Bogies with a carrying axle and a motor axle are used on the Italian

(1) Tables 1 to 9 are given as appendices to Part I.

State locomotor E 330, 431 (Zara) and E 432; their construction is also the same as that of such bogies on steam locomotives.

The *passenger carriages* used for high speeds are usually eight-wheeled and it is only exceptionally that six-wheeled or even four-wheeled carriages are used. In recent times the coaches have been built with metal bodies as these are safer at high speeds. The outside of the body is made as smooth at possible, so that the air resistance, when running, may be reduced to the minimum. Inside the body is lined out with metal or wood. The floor is metal covered with a layer of magnesian cement, or is a metal and wood, or a double wood floor. Carriages with wood bodies are also in use in trains running at high speeds.

The rail motor coaches only exceptionally attain speeds of 90 km. (56 miles) per hour [the electric motor coach of the French State Railways, 90 km. (56 miles) per hour; French Midi 85 km. (53 miles) per hour; and the Czechoslovakian State Diesel electric now being built a speed of 90 km. (56 miles) per hour], and consequently most of these carriages do not come within the present report. The design so far as it concerns their adaptation to high speeds follows that of eight-wheeled passenger carriages, the bogies naturally being arranged to enable the electric motors to be fitted. They are generally coupled to a trailer.

The steam rail motor coach of the Egyptian State Railways differs in construction from other such vehicles as it consists of two bodies carried on two outer pairs of wheels with a centre bogie common to the two bodies and also carrying the steam boiler. The details of the construction of this vehicle are however not given.

A. — **Steam and electric locomotives.**

1. *Overall wheel base, distance between pairs of wheels, weight per axle, and diameter of the wheels.*

2. *Rigid wheel base and guided length.*

3. *Length of the radius rod of the carrying pairs of wheels and bogies required for them to suit the curves.*

The *overall wheel base* depends upon the essential features in the design of the engines (output, axle load, wheel diameter); this distance varies between the limits shown in the following table :

Wheel arrangement.	Total wheel base. C	Rigid wheel base. P	$\frac{C}{P}$	Guided length.
	Millim. (*Ft.-in.*).	Millim. (*Ft.-in.*).		Millim. (*Ft.-in.*).
4—4—0	7 035—8 000 (23 ft. 1 in.—26 ft. 3 in.).	2 744—3 000 (9 ft.—9 ft. 10 1/8 in.).	0.37—0.4	6 046—6 900 (19 ft. 10 in.—22 ft. 6 11/16 in.)
4—4—2	8 500—10 750 (27 ft. 10 5/8 in.—35 ft. 3 1/4 in.)	2 090—4 650 (6 ft. 10 9/32 in.—15 ft. 3 in.).	0.21—0.53	5 065—7 550 (16 ft. 7 11/16 in.-24 ft. 9 1/4 in.)
4—6—0	7 885—9 100 (25 ft. 10 7/16 in.-29 ft. 10 1/4 in.)	3 930—4 950 (12 ft. 10 3/4 in.—16 ft. 3 in.).	0.49—0.56	6 885—8 000 (22 ft. 7 in.—26 ft. 3 in.).
4—6—2	10 420 (34 ft. 2 1/4 in.).	3 900—4 200 (12 ft. 9 9/16 in.—13 ft. 9 3/8 in.).	0.35—0.39	6 420—7 200 (21 ft. 3/4 in.—23 ft. 7 1/2 in.).
4—8—0	9 540 (31 ft. 3 5/8 in.).	3 550 (11 ft. 7 13/16 in.).	0.37	8 270 (27 ft. 1 3/8 in.).
4—8—2	13 170—13 200 (43 ft. 2 1/2 in.—43 ft. 3 3/4 in.)	6 000—6 150 (19 ft. 8 1/4 in.—20 ft. 2 in.).	0.45—0.47	8 500—8 850 (27 ft. 10 5/8 in.—29 ft. 7/16 in.)

From the above information the *maximum rigid wheel base* and its *ratio* to the total wheel base, as well as the limit of the « *guided lengths* » can be found.

The *guided length* is the longitudinal distance of the parts of the running gear (pairs of wheels, bogie centres, etc.) upon which the lateral reactions act like a lever arm, i. e. which decide the position of the longitudinal axis of the vehicle on the straight and on the curve, centrally or uncentrally with the track.

As regards the *distance between individual pairs of wheels*, the wheel base of the *bogies* must be mentioned. Leaving aside the two old English types [Belgian National Railway Company, (types 17, 18)] with a bogie wheel base of 1981 mm. (6 ft. 6 in.), the wheel base varies in the case of locomotives built on the Continent, between 2 000 mm. (6 ft. 6 3/4 in.). [Paris-Lyons-Mediterranean, 230 C, 230 A) and 2 500 mm. (8 ft. 2 7/16 in.) (Jugoslavia 4-6-2)]; the ratio of this wheel base to the standard-gauge track [1 435 mm. (4 ft. 8 1/2 in.)] gives 1.39 and 1.74.

The *distance from the trailing pairs of wheels* to the trailing coupled pairs of wheels also varies with the number of coupled wheels. For the 4-4-2 type this distance is 2 400 to 3 200 mm. (7 ft. 12 1/2 in. to 10 ft. 6 in.) [omitting the standard length of 3 900 mm. (12 ft. 9 9/16 in.) on the Belgian National Railway Company 69], for the 4-6-2, 2 300 to 3 700 mm. (7 ft. 6 9/16 in.) (Rumanian Railways, 23 100) and for the 4-8-2, 3 270 to 3 600 mm. (10 ft. 8 3/4 in. to 11 ft. 9 3/8 in.) (Polish State, Pu 29).

The allowable axle load plays a very great part in the design. In 43 classes of engines the distribution of the load is as follows :

14 - 14 9 (*13.8—14.7*)	15 – 15.9 (*14.8—15.6*)	16—16 9 (*15.7—16.6*)	17 – 17.9 (*16.7—17.6*)	18—18.9 (*17.7—18.6*)	19—19.9 (*18.7—19.6*)	22.4 *22.0*
← Metric (*English*) tons. →						
2	3	6	9	18	4	1

The heaviest load of 22.4 metric (22 English tons) is on the Belgian type 10 locomotive. Next between 19 and 19.9 t. there is another Belgian locomotive (type B 7) and three French locomotives : State 231; Nord, 3.1251; Paris-Orleans, 3641. In the lower range of 18 to 18.9 t. are found the French Est locomotives (with the three classes 3100, 31000 and 241000); the Midi (3501, 3001, 3101); Alsace-Lorraine (S 14) and Paris-Lyons-Mediterranean (231 D). For the rest of Europe; Italian State (691); Polish State (Pu 29), and the Egyptian State. In the limits 17 to 17.9 are the Rumanian State, 231000, and Jugoslav State, 4-6-2 and finally in the 16 to 16.9 range, the Paris-Lyons-Mediterranean (Algerian lines), and Czechoslovakian State, 387.O. The Paris-Lyons-Mediterranean (Algerian lines, 230 C) has the lowest axle load, 14.45 t. (14.22 Engl. tons).

The *weight in working order* of these locomotives varies between 52.4 (51.6 Engl. tons) (Belgian National Railway Company, type 17) and 117.18 t. (115.3 Engl. tons) (French Est, 241000).

As regards the diameter of the coupled wheels, there is a tendency to use smaller diameters than formerly, even for high speeds, and the limits have been considerably widened, as to the number of revolutions per minute allowed, without any drawbacks occurring in working.

Thus, the Rumanian State locomotives 231000, for a speed of 120 km. (75 miles)

per hour, and a wheel diameter of 1 855 mm. (6 ft. 1 in.), and the Italian State Railway locomotive 691, with a speed of 130 km. (81 miles) per hour and a wheel diameter of 2 030 mm. (6 ft. 8 in.) make the same number of revolutions per minute, 344; in addition, the French Nord locomotive 3.1251, and the Paris Orleans 3501, 3591 and 3641, at a speed of 120 km. (75 miles) per hour and with a wheel diameter of 1 900 mm. (6 ft. 3 19/32 in.) make 336 revolutions per minute (and a whole series of other locomotives give 328 revolutions per minute).

The diameters of the leading carrying wheels vary between the limits of 900 and 1 125 mm. (2 ft. 11 1/2 in. and 3 ft. 8 9/32 in.); (Italian State, 671); and as an exceptional case, 810 mm. (2 ft. 7 7/8 in.) for the Paris-Orleans locomotive 171 S; the trailing carrying wheels have a diameter of from 1 080 mm. (3 ft. 6 1/2 in.) (French Est, 241000) to 1 500 mm. (4 ft. 11 in.) (Paris-Orleans, 3001).

A whole series of 4-6-2 type locomotives use bissel trucks, as do the 4-4-2 and 2-8-2 type locomotives. The length of their radius rod varies between 1 575 mm. (5 ft. 2 in.) (French State, 231; Alsace-Lorraine, S 14; French Est, 31000; Paris-Orleans, 3641) and 2 400 mm. (7 ft. 10 15/32 in.) (French Est, 241000).

Table 1 shows that the *total wheel base of the electric locomotives* with two four-wheeled motor bogies is between 8500 and 8950 mm. (27 ft. 10 5/8 in. and 29 ft. 4 3/8 in.). The wheel base of the different bogies varies between 2700 and 2950 mm. (8 ft. 10 5/16 in. and 9 ft. 8 5/32 in.) and the distance between their centres between 5 700 and 6 100 mm. (18 ft. 8 7/16 in. and 20 feet). The rigid wheel base is conditioned by the wheel base of the bogies, whereas the guided length is decided by the distance between the bogie centres.

Locomotives with *driving* wheels carried in the main frame and with carrying bogies have a wheel base limit proportionally greater, 8 400 to 14 150 mm. (27 ft. 7 in. to 46 ft. 5 in.). The figure corresponds to the total length of the locomotive, over buffers, of 10 990 to 17 780 mm. (36 ft. 11/16 in. to 58 ft. 4 in.). The wheel base of the *four-wheeled bogies* is 2 000 to 2 400 mm. (6 ft. 6 3/4 in. to 7 ft. 10 5/32 in.); the Zara bogies and the Italian bogies (330, 431 and 432) with carrying and driving wheels have a wheel base of 2 400 to 2 600 mm. (7 ft. 10 5/32 in. to 8 ft. 6 23/64 in.). As regards the fixed wheel base of the wheels in the main frame, in the case of the Midi 3101, Paris-Orleans 501 and 502 locomotives, it is 4 000 and 5 750 mm. (13 ft. 1 1/2 in. and 18 ft. 10 25/64 in.); the guided length is 6 600 to 8 600 mm. (21 ft. 8 in. to 28 ft. 2 5/8 in.). The locomotives with trucks have the rigid truck wheel base of 4 600 mm. (15 ft. 1 in.), and a guided length of 7 650 mm. (25 ft. 1 in.). The *diameters* of the wheels are usually, for carrying wheels, 900 to 1 110 mm. (2 ft. 11 1/2 in. to 3 ft. 7 11/16 in.), and for the driving wheels of locomotives with motor bogies or trucks 1 200 to 1 600 mm. (3 ft. 11 15/64 in. to 5 ft. 3 in.); in the other group, from 1 630 to 1 750 mm. (5 ft. 4 5/32 in. to 5 ft. 8 29/32 in.). The *axle load* of the electric locomotives are the same as that of steam locomotives on the different administrations; thus on the Midi Railway it is 18 and 19.45 t. (17.7 and 19.15 Engl. tons); Paris-Orleans, 17.3 tons to 18.7 t. (17.0 to 18.4 Engl. tons); Italian State (325), 15 to 21 t. (14.8 to 20.7 Engl. tons); French State, for the E locomotor only, 15.65 t. (15.4 Engl. tons).

* * *

4. *What is the amount of the side movement (from the centre line of the vehicle towards each side) :*

a) *of bogies with carrying wheels, or with carrying and driving wheels (for*

example, Krauss-Helmholtz, Zara, designs, etc.);

b) *of the motor bogies of electric locomotives;*

c) *of each of the pairs of coupled wheels and on electric locomotives, of the pairs of driving wheels ?*

5. *What wheels have reduced flanges and how much are the flanges thinned down ? What wheels have no flanges ?*

The lateral side movements (on both sides) are given in table 2 for the guided bogies, the trailing motor axles and also for some coupled axles of the steam locomotives.

This table also gives various methods of reducing the flanges so that curves of small radius may be negotiated more easily.

The *extreme side movement of the bogies* depends on the method of coupling of the locomotive, and amounts to, for type 4-6-0 locomotives, from 19 to 40 mm. (3/4 inch to 1 9/16 in.) (Belgian National, 66); type 4-4-2, 40 to 55 mm. (1 9/16 in. to 2 3/16 in.) (Nord 2643); for type 4-6-0, 38 to 80 mm. (1 1/2 in. to 3 5/32 in.) (Belgian National 7, 9); type 4-6-2, 45 to 83 mm. (1 49/64 in. to 3 1/4 in.) (Paris-Orleans 3591); type 4-8-0, 40 mm. (1 9/16 in.); and type 4-6-2, 100 to 125 mm. (3 15/16 in. to 5 in.) (Est 241000).

The *trailing carrying pair of wheels* is in some locomotives of the 4-4-2 type fixed, or has a lateral side movement up to 37 mm. (1 29/64 in.) (Belgian National 69). In the 4-6-2 type locomotives, these axles have all a side movement, with for exemple a side movement of between 25 mm. (1 in.) (Italian State 691), and 92 mm. (3 5/8 in.) (Est 31000); and in the 4-8-2 type locomotives, of between 100 and 150 mm. (3 15/16 in. and 6 in.), (Est 241000).

The *coupled axles*, safe in exceptional cases, have no side movement viz.:

a) the last coupled axle in the type 4-6-2 locomotives : Paris-Lyons-Mediterranean, 230 A, [16 mm. (5/8 in.)] and Italian State, 671, [10 mm. (3/8 in.)]; *b*) the trailing coupled axle in type : 4-8-0, Polish State S 24 [26 mm. (1 1/32 in.)]; *c*) the third coupled axle in type 4-8-2, Poland Pu 29 [30 mm. (1 3/16 in.)].

The axles have only very little play in axle boxes, this varying between 0.8 mm. (0.031 in.) (Egyptian), and 2.5 mm. (0.098 in.) (Paris-Orleans 3591); in most cases it is only 1 mm. (0.039 in.).

In locomotives with the Italian bogie at the leading end (Italian State 640, 685, 746) the bogie journal has a transverse movement of 30 to 45 mm. (1 3/16 to 1 49/64 in.), whereas the leading coupled axle moves 10 mm. (3/8 in.) on each side of the centre. In the Italian State locomotives 746 and 691, the centres of the trailing truck have also 40 to 50 mm. (1 9/16 to 1 31/32 in.) side movement.

As regards *reducing the thickness of the flanges* of each pair of wheels to the dimension needed, the extreme movements of the bogies and trailing carrying wheels of steam locomotives are considered, so that curves of small radius may be negotiated more easily; the summary of the exact values reported is as follows : In all type 4-6-0 coupled locomotives, the flange of the first coupled axle is made 5 to 10 mm. (3/16 in. to 3/8 in.) thinner. In the type 4-4-2 locomotives, seeing that there is a fixed trailing driving axle, either one (Belgian National, 6) or two (Nord, 2743; Paris-Orleans, 30001) coupled axles have the flange thinned by 2 to 16.4 mm. (5/64 in. to 43/64 in.); as the trailing axle is radial in the Belgian No. 69 class, the flange of the first coupled pair of wheels is reduced by 5 mm. (3/16 in.); in the Egyptian locomotives, however, all the flanges are standard. In the type 4-6-0 locomotives there are three cases : either the flanges of all the wheels are standard, seeing that the trailing wheel is radial, or the flanges of the two first

pairs of coupled wheels are reduced (Est, 3100; Paris-Orleans, 4001), or as in most cases, the middle pair of coupled wheels has the flanges reduced [between 5.3 and 16.4 mm. (13/64 in. and 43/64 in.)] between the two outer coupled pairs of wheels with standard flange sections. In the type 4-6-2 locomotives, three methods of doing this are also found: all the flanges are standard (French State, 231; Alsace-Lorraine, S 14; Est, 31000) or the two first pairs of coupled wheels have the flanges reduced [Nord 3. 1251; Paris-Orleans, 3501 and 4501 — by between 2 to 16.4 mm. (5/64 in. and 43/64 in.)], or finally the centre pair of coupled wheels has its flanges reduced, which is the most usual arrangement as with the 4-6-0 type. The tyres of the bogie wheels in the Est 31000 have flanges 5 mm. (3/16 in.) thicker, i. e. they are increased to a thickness of 37.5 mm. (1 15/32 in.).

The most interesting point is the thickness of the flanges in respect to the play between the flange and the rail of the type 4-8-2 locomotive. Whereas in the Est locomotive 241000 the flanges of the leading bogie have also the 5-mm. (3/16 in.) thicker section [from the standard section of 32.5 mm. to 37.5 mm. (1 9/32 in. to 1 15/32 in.)] which, in view of their small wheel base of 2 100 mm. (6 ft. 10 9/32 in.), contribute to good running, the thickness of the flanges of the coupled wheels are 20.2, 25.7, 25.7 and 31 mm. (13/16 in., 1 1/32 in., 1 1/32 in. and 1 7/32 in.), i. e. reduced by 12.3, 6.8, 6.8, and 1.5 mm. (1/2 in., 1/4 in., 1/4 in. and 1/16 in.); the trailing driving pair of wheels has a standard thickness of 32.5 mm. (1 9/32 in.).

With the extreme lateral movements of the bogie, of 125 (5 in.) and of the truck, 150 mm. (6 in.), this locomotive can negotiate curves of a radius of 100 m. (5 chains) in spite of its total wheel base of 6 150 mm. (20 ft. 2 in.).

On another locomotive, the Polish State Pu 29, the flanges of the wheels of the third radial axle are reduced by 30 mm. (1 3/16 in.); the tyres on the second pair of wheels are without flanges as is shown in the sketch No. 29 of table 5.

In the case of *electric locomotives* with 2 motor bogies, the body centres have no transverse movement; on some of them the centre can move longitudinally [Midi 4601 — 27 mm. (1 1/16 in.); Paris-Orleans EBB 225)]. In the locomotive with the driving axles carried in the frame, the centres of the four wheeled carrying bogies can move transversely 50 to 150 mm. (2 to 6 inches) (Paris-Orleans 501; Italian State E 326); in the Zara or Italian bogies, 35 to 50 mm. (1 3/8 in. to 2 in.); in these latter the leading pair of coupled wheels can move transversely 10 to 20 mm. (3/8 in. to 3/4 in.) [French State 401 (all the 4 driving axles, to the extent of 25 mm. (1 in.)], and in the Italian State E 330 (the second, of 20 mm. (25/32 in.). The radius bar pins usually have 0.5 to 2.5 mm. (0.02 in. to 0.1 in.) play in the axle box (Paris-Orleans EBB 1). All the tyres have standard thickness flanges; the middle driving pair of wheels alone of the Midi E 3101 has the flanges reduced by 16.25 mm. (5/8 in.).

* * *

What are the centering mechanisms used on the carrying wheels, the bogies with carrying wheels only, and the bogies consisting of carrying wheels and driving wheels; furthermore, what are the initial and final tensions of these arrangements controlling the longitudinal axis of the vehicle?

The centering mechanisms are different on the bogies and on the trailing carrying pairs of wheels of *steam locomotives*, no particular arrangement predominating; a summary of the different arrangements is given in table 3.

According to this, the arrangements

used for controlling the *side movement* are as follows :

a) 2 horizontal side plate springs coupled by links, or in the case of the Est 241 000, by means of auxiliary helical springs;

b) 2 side helical springs;

c) bolster with swing links :

1) ordinary, either perpendicular or inclined;

2) with triangular 2-point suspension, one of which alternately acts as point of rotation during extreme movements (Belgian National 7, Paris-Orleans, 171 S and 3591).

d) inclined surfaces, 15 and 20 % (Paris - Lyons - Mediterranean, 231 D, 230 C, 230 A.M);

e) bolster with volute centering spring (Italian State 671 and 691 on the ordinary bogies, Italian State 640, 685 and 746 on the Italian bogies).

It is not usual to arrange any centering mechanism to restore the locomotive to the longitudinal axis of the bogie after a partial rotation round the central spherical pivot. This is done however on the Paris - Lyons - Mediterreanean (231 D, 230 C, 230 A.M) by means of a helical bearing.

The *force* with which the respective carrying wheels of the bogie are returned to the central position lies within the following limits :

1. laminated springs (all under initial tension) : initial compression of 450 to 6 940 kgr. (990 to 15 300 lb.); final compression 3 480 to 7 800 kgr. (7 670 to 17 200 lb.);

2. helical springs either without initial compression or with 4 500 kgr. (9 900 lb.) compression; the final compression varies from 4 220 to 9 500 kgr. (9 300 to 20 950 lb.);

3. inclined surfaces, the initial compression is usually 4 004 kgr. (8 830 lb.) and the final compression 4 519 kgr. (9 960 lb.);

4. bolsters :

a) with ordinary swing links the maximum force has a value of 3 315 to 10 500 kgr. (7 300 to 23 150 lb.);

b) with triangular links the initial force is 1 480 to 4 430 kgr. (3 260 to 9 760 lb.), the maximum force is 5 450 to 8 880 kgr. (12 000 to 19 570 lb.).

5. on the bolsters with helical springs the initial compression is 1 800 to 2 000 kgr. (3 970 to 4 400 lb.), the final compression is 2 800 to 3 000 kgr. (6 170 to 6 600 lb.).

The centering mechanisms of the *electric locomotives* (see table 8) are also very varied; on some locomotives with motor bogies the bogies are coupled together by a drawbar fitted with springs and small spherical buffers (Midi 4601) or solely by means of a drawbar with an initial compression of 9 500 kgr. (20 940 lb.) (Paris-Orleans EBB 225).

In the 2 other groups the laminated control springs have an initial compression of 2 000 to 4 000 kgr. (4 400 to 8 800 lb.); final compression of 3 720 to 7 400 kgr. (8 200 to 16 300 lb.) (Midi 3101, Paris-Orleans E 601); the inclined and helicoidal surfaces have an initial force of 3 140 kgr. (6 920 lb.) (Paris-Lyons-Mediterranean 262 AE); the bolster with swing links and volute springs has an initial compression of 1 800 to 2 000 kgr. (3 970 to 4 400 lb.); final compression 2 800 to 3 000 kgr. (6 170 to 6 600 lb.) (Italian State E 332 and 432 on the Italian bogie).

The radius bar of the Zara bogies (Italian State 330 and 431) has only volute springs with an initial compression of 1 800 kgr. (3 970 lb.), and final compression of 2 800 to 3 000 kgr. (6 170 to 6 600 lb.).

Interesting special centering mecha-

nisms are used on the Paris-Orleans 501, 502, 401, 402 and Italian State E 326. On the first of these locomotives the 4 angular levers are coupled in pairs by helical springs; the pulley wheels on these levers cause the sliding bogie centre to return between these springs into a position co-axial with the axis of the locomotive (see figs. *c, d, e* of table 4). On the other locomotive, the movement of the bogie centre is coupled up with the movement of the adjacent 2 driving axles by an arrangement as shown in figs. *a, b*; this arrangement however does not come into action on curves of less than 200-m. (10 chains) radius.

On the third locomotive there are 2 levers in the form of tongs between the 2 shortest arms of which the bogie centre moves, while the longer arms are connected by a volute spring with initial compression of 2 000 kgr. (4 400 lb.) and final compression of 3 000 kgr. (6 600 lb.). On the Paris-Orleans E 601, the body centres are carried on the bolsters by elliptical springs; the extreme side movement of the bolster is 20 mm. (13/16 in.) and the return springs have an initial compression of 2 000 kgr. (4 400 lb.) and a final compression of 4 410 kgr. (9 720 lb.).

7. *What are the maximum speeds at which the vehicles are run, on the straight, with what minimum radii of curves on open line; what is the radius of this curve, and what is the superelevation and how much is the gauge widened ?*

The maximum speed of *steam locomotives* varies. This speed is 80 km. (50 miles) per hour for the Egyptian locomotive with driving wheels 1 981 mm. (6 ft. 6 in.) in diameter; 90 km. (56 miles) per hour for the Paris-Orleans S 24 with wheels of 1 750 mm. (5 ft. 8 9/32 in.) and 95 km. (59 miles) per hour for the Paris-Lyons-Mediterranean, 230 A, with wheel diameter of 1 650 mm. (5 ft. 5 in.); moreover the majority of the locomotives run at the speed of 100 km. (62 miles) per hour (7 locomotives), 110 km. (68 miles) (16 locomotives), 120 km. (75 miles) (14 locomotives) and at the maximum speed of 130 km. (81 miles) per hour (Italian State 691).

In the *electric locomotives* of the first group the speed is 90 km. (56 miles) per hour (Midi, 4601, Paris-Orleans EBB1 225); 95 km. (59 miles) per hour (Paris-Orleans, EBB 101), and 110 km. (68 miles) per hour (French State locomotor); in the 2nd group 100 km. (62 miles) (Italian State 330, 332, 431, 432); 120 km. (75 miles) (Midi 3101, Paris-Orleans 501, 401) and 130 km. (81 miles) per hour (Italian State E 326); in the 3rd group 105 km. (65 miles) per hour (Paris-Orlenas E 601).

The different speeds on the curves and when running through switches are given in Part II « Track ».

* * *

8. *What is the tyre profile on standard wheels; what is the section for wheels with thin flanges; what is the section for wheels without flanges ? On what is the selection of these profiles particularly based ?*

The sections of tyres of normal thickness and with reduced flanges (or without flange) are indicated in table 5.

The choice of the flange sections is usually governed by the locomotives having to work over curves of small radius; only a few administrations give the thickness of the tyres on a straight line 10 mm. (3/8 in.) below the point of contact. In the case of standard sections, in the majority of cases this thickness is 32.5 mm. (1 9/32 in.) (French Railways), or 32 or 31 mm. (1 17/64 in. or 1 1/4 in.). The No. 10 section (Est) has the flange thickened up to 37.5 mm. (1 15/16 in.). The tyres with thinned down flanges have the flange reduced by 2 mm. (5/64 in.) (Nord, section 17) to 19.5 mm. 25/32 in.) (Nord section 18), i. e. to a thickness of

30.5 mm. (1 3/16 in.) and 13 mm. (33/64 in.) respectively. When specially given the angle of the face of the flange to the horizontal plane is usually 70°.

B. — Passenger coaches and motor coaches.

1. *The total length over buffers, the total wheel base, the distance between each pair of wheels; in the case of bogie coaches, the distance between bogie centres also; the axle load and the diameter of the wheels.*

2. *Distance between the 2 pairs of wheels of the wagons and of the bogies determining the position of the coach or of the bogie relatively to the track and which play the role of guiding wheels in the track.*

3. *Do you use exclusively bogie coaches behind the locomotives described in I-A, or*

4. *Also wagons with 2 or more pairs of wheels under a common frame?*

The running gear, i. e. in the case of bogies, the side play of each axle from the centre position towards each side, and in the case of radial axles, the movement of their axle boxes, in the longitudinal direction of the coach towards each side — angle of rotation — the angle of rotation of the bogies, the play of the body bolsters, etc.

Same information in respect to the design of the centering gear, as well as the magnitude of the centering forces; also as to the maximum running speed allowed for these coaches.

5. *Have you introduced any devices to asure steady running without any hunting in order that the bodies of vehicles coupled together shall remain in contact such as by means of vestibule connections kept pressed one against the other or by some special coupling?*

6. *Have you introduced any special design of bogie in order to improve the running of the stock at high speeds and what results have you obtained?*

7. *What instructions are in force in the workshops as regards accurately checking over the bogies and bodies, as well as upon repairing the bogies and the stock after a given period in traffic?*

As mentioned in the general part of this report, carriages on 2 four-wheeled bogies are used principally for high speeds, although some Administrations also use 6-wheeled vehicles (Paris-Lyons-Mediterranean, Polish State, and even 4-wheeled service vans and brake vans (Nord, Paris-Orleans, Rumanian State, Czechoslovakian State), in order to reduce the weight of the train. The cases however in which these vehicles are allowed in the trains is limited, for example on the Paris-Orleans to the 4-wheeled vehicles with a minimum wheel base of 6 m. (19 ft. 8 1/4 in.), on the Polish State to 6-wheeled vehicles with a minimum overall wheel base of 6 m. (19 ft. 8 1/4 in.) and a weight of at least 16 t. (15.7 Engl. tons), etc.

The *carriage bogies* have 2 pairs of wheels and are principally of the 2 types known as the « International » and the « Pennsylvania ». The first type of bogie has the bogie frame suspended on the axles by means of 4 independent springs, which are in turn carried by helical springs. The body is carried on the bogie frame through the centre (spherical, plain or stepped), and the bolster which is suspended by 2 groups of elliptical laminated springs.

This type of bogie is however being replaced more and more by the « Pennsylvania » type which differs from it in that the bogie frame is carried on the pairs of wheels by means of equalisers equalising the weight on the wheels on each side. The frame is suspended from these equalisers by helical springs. The axle boxes are either provided with cast iron bearings lined with antifriction

metal and with lubricating pads conveying the oil to the journals, or with a device feeding the oil from above the journals; or again roller bearing boxes are used. The bogies, in the older designs, were built up of pressed steel plates and steel rolled sections; in the most recent designs cast steel is used more and more frequently for the connections, parts of the bolsters, etc.; the monobloc system in which the whole of the bogie frame is cast in a single piece has recently become the most usual. This method has the advantage that all the details can be correctly designed while getting a minimum weight.

The bolster is built of rolled sections, or pressed plates, or cast steel. It is frequently lined with wood to reduce the noise.

The principal details of the different classes of carriages are given in table 6. The length of the vehicle (over buffers) is as much as 22 530 mm. (73 ft. 11 in.) and the length of the body 22 200 mm. (72 ft. 10 in.). The axle load in the case of a passenger carriage, is 13.0 t. (12.8 Engl. tons) at the maximum. The diameter of the wheels is 920 to 1 143 mm. (3 ft. 1/4 in. to 3 ft. 9 in.). The distance between bogie centres varies between 12 630 and 15 502 mm. (41 ft. 5 1/4 in. and 51 ft. 2 in.); the wheel base of the bogies is 2 438 to 3 000 mm. (8 feet to 9 ft. 10 1/8 in.).

In the case of the bogie carriages, the play of the bearing on the journal is 1 to 4 mm. (3/64 to 5/32 in.). 1 mm. being the most usual; the Belgian National Railway Company's vehicles have a play of 4 mm. at the inside of the centre bearing whereas on the outside it is 1 mm. (3/64 in.). The play in the guides is 0.5 to 5 mm. (5/256 in. to 3/16 in.) transversely, usually 2 mm. (5/64 in.) and 0.5 to 3 mm. (5/256 to 1/8 in.), usually 2 mm. (5/64 in.) longitudinally.

The *side movement of the bolster* is 15 to 55 mm. (1/8 in. to 2 3/16 in.), most usually 15 to 20 mm. (5/8 in. to 13/16 in.); and the longitudinal play 2 to 3 mm. (5/64 in. to 1/8 in.). The angle of deviation of the bogies is 5° to 10°, 6° being the usual practice.

Six-wheeled vehicles are sometimes used, even in high-speed trains (Paris-Lyons-Mediterranean); the outer pairs of wheels are radial, with a play of 1 mm. (3/64 in.) on the journal, and with 5 mm. (3/16 in.) transversely, and 21 mm. (53/64 in.) longitudinally in the guides; they are 8 400 mm. (27 ft. 6 3/4 in.) apart, and their maximum deviation is 1°21′. The middle axle can move 1 mm. (3/64 in.) transversely on the journal, and 35 mm. (1 3/8 in.) in the guides, as well as 2.5 mm. (3/32 in.) longitudinally. The centering gear by which the bogie is returned to the normal position consists usually of swing links arranged at an angle to the perpendicular axis of the carriage, carrying the bolster. These links are either a fixed length or the length can be adjusted by means of a screw. In certain cases small buffers are fitted on the frame (Paris-Lyons-Mediterranean type Dd^2y^2). Some Administrations prefer the links to be of a fixed length, as this prevents any error in setting the bolster. The correct buffer height is obtained by inserting packing pieces under the elliptic springs (Italy).

The Railways obtain steady running at high speeds by tightening up the couplings. With the same object, some railways have increased the bogie wheel base from 2 500 to 3 000 mm. (8 ft. 2 7/16 in. to 9 ft. 10 1/8 in.) (Paris-Lyons-Mediterranean, Italian State).

The Railways take care that the stock used for high speeds is in perfect order by periodical overhauls and by checking over the angles of the bogie frame after repairs. In addition to the daily repairs, a very careful examination and the necessary repairs are carried out at intervals of not less than 3 to 6 months, usually between 9 months up to 2 years, or after having run 90 000 to 100 000 km.

(56 000 to 62 000 miles). Special importance is given to the symmetrical springing of the bolster and to the bogie being horizontal while maintaining the buffer height.

II. — Method of carrying the body on the bogies and position of the centre of gravity.

1. *On how many points is the sprung weight of the carriages mentioned in the 1st part carried ?*

2. *What is the sprung weight carried on each axle; and what is the weight of the unsprung weight ?*

3. *a) Do the outer axles carry a lower weight than the intermediate axles ? What percentage of the axle load have you on the driving axles ?*

b) Are the leading carrying axles or also the leading coupled axles the only ones with a reduced weight per axle; if so, what tests did you take into account to arrive at the reduced weight ?

4. *Are the coal bunker and the water tanks so arranged on the tenders that the variation in axle load is reduced to a minimum when the quantities are increased or reduced ?*

5. *What is the height of the centre of gravity of the whole of the vehicles above rail level ? What is the height of the centre of gravity of the sprung mass of the steam locomotives and of the electric locomotives ? What experience have you obtained as regards the oscillations about the parallel horizontal axis (rolling) ?*

6. *What is the factor of safety of the locomotives and the tenders against turning over on the smallest radius curves on the open line, particularly in the event of a spring breaking at the maximum speed allowed on these curves, or due to irregular variations in the level of the track (dissymmetrical variations of level of as much as 20 mm. (13/16 in.) ? What safety measures have been provided ?*

1. Table 7 shows in diagram form how the *steam locomotives* are carried. In order to arrive at the number of points on which the sprung weight of the vehicle is supported, on the one hand, we will consider the centre of gravity of the various methods of suspension taken together, and on the other, the points of support on the bogie; in this latter case when the weight of the locomotive is carried on the centre bearing of the bogie, this is taken as one of the points of support, ignoring the fact that if the inclination increases the weight of the locomotive, it will also come onto one of the side bearings if these are fitted. The extent to which the different wheels of the bogie are equalised varies according as there are one or two supports, spherical or plain, and according as a bogie bolster or equalising levers are used or not.

The predominating tendency is to compensate the load carried on the separate bearing springs by equalisers, this tendency being greater in the case of 6-coupled engines. This tendency results in there being 3 points of support, when the bogie has only a single support and the bearing springs of the trailing axles are connected with the other springs by equalisers; or in there being 4 or 6 supports, when the bogie has 2 lateral bearings and one pair of trailing carrying wheels independently sprung.

Obviously this method of carrying the locomotive whereby the load on the bearing springs is kept uniform, and consequently the engine runs steadily as well as being less likely to derail, even on lines in not too good order, does not apply to the new 8-coupled locomotive of the Est, No. 241000, which has each pair of wheels independently sprung so that there are 11 suspension points. The Paris-Lyons-Mediterranean 6-coupled locomotive 4-6-0, No. 230A (Algerian Lines) also with independently sprung driving wheels, has 7 points of support.

The railways on which the locomotive is carried *on one bogie bearing* are : Bel-

gian National Railway Company (except 2 locomotives of classes 66 and 69 of German origin); Paris-Lyons-Mediterranean, French Est, Italian State and Czechoslovakian State; on the other hand the French Nord, Egyptian State, Midi, Polish State and Rumanian State Railways use 2 *supports* on the bogie exclusively. The French Est Railway, on the new locomotive 241000, has 2 supports but on its other locomotives only one. In the case of the Alsace-Lorraine Railways the German locomotive S1O1 has 2 points of support; in the case of the locomotives built to its own designs one point of support is used; the Paris-Orleans Railway uses 2 points of support arranged almost identically. In the same way *the form of the support* varies considerably and can be divided, in the case of a single bearing, into plain and spherical bearings; in the case of 2 points of support, the side spherical bearings are rather more numerous. The Egyptian State, Alsace-Lorraine, Italian State and French State use plain bearings only; the Belgian National Railway Company only uses spherical bearings (except in the case of locomotives of German and English design); the Paris-Lyons-Mediterranean, Czechoslovakian State, Nord, Midi and the other Administrations (Est, Paris-Orleans, Polish State and Rumanian State Railways) use both designs.

The *electric locomotives* (cf. table 8) with carrying bogies are so arranged that the body is carried on 2 points. Each bogie wheel is carried on a special spring (Midi, 4601; Paris-Orleans, EBB 101, 225), or each side of the bogie is carried on the yoke, by a longitudinal spring (Paris-Orleans EBB 1; French State locomotor), on which the frame is carried. The locomotive of the Paris-Orleans Railway EBB 225 is fitted with elliptical laminated springs on the bolster in addition to the 4 bearing springs. In all the locomotives the body is carried on the bogie by a single central pivot, which is either flat and of large diameter (Paris-Orleans, EBB 1, 101), large diameter disc (French State locomotor), dished (Midi 4601), or spherical and convex (Paris-Orleans, EBB 225).

The second group of electric locomotives shows great diversity in the way the body is supported and in the spring suspension : the 4 bearing points are either arranged in lozenge form with one point of support (by central equaliser) on each bogie, the 2 other points being by suspension on the 4 driving axles, with longitudinal equalisers on each side (Paris-Orleans locomotive E 2 D 2, No. 501; Italian State, E 332), or as in the case of the Paris-Orleans locomotive E 2 D 2, No. 401, there are 4 identical equalised groups, each set bearing on two driving axles, with a longitudinal equaliser, and being combined, through a lever arrangement, with the suspension spring on the adjacent bogie (see fig. *f*, table 4).

When there are 6 bearing points these locomotives have either bogies with a single support under the body bolster (Italian State, 432) or bogies with 2 points of support (Midi, 3101). In the first case the 2 driving wheels are independently sprung, in the second case the springs of the 3 driving pairs of wheels are connected together by equalisers. In the case of the Italian State locomotive E 431, there are 8 bearing points, i. e. 2 on the 2 Zara type bogies (4 springs connected by a longitudinal equaliser) and 2 on the intermediate driving wheels also independently sprung.

On the locomotives with *motor trucks* the body is carried on each truck through the centre; each truck has 3 points of support, i. e. one on the bogie, one at the centre of gravity of the springs of the 3 pairs of wheels connected by the equalisers. In the case of the Paris-Orleans locomotive E 601 the body centre is carried on the body bolster which is carried from the truck frame by means of elliptical springs. The centre bearing pin of one bogie of the Paris-Lyons-Me-

diterranean locomotive 262 EAE bears on disc springs; the body is in addition supported by 2 spring side bearings with helical springs in the transverse section of the centre and in addition by 2 lateral spring supports with conical coiled springs on the outside of the frame between the 3rd and 4th and the 7th and 8th axles. The bogies of the 2 locomotives have one longitudinal spring on each side.

The *6-wheeled tenders* are all carried on 4 points of support so arranged that the 2 trailing pairs of wheels have their springs connected together by longitudinal equalisers; the Midi Railway tender No. 1921 is carried on independent springs at 6 points. The *8-wheeled* tender, as far as it is possible to judge from the data supplied, has either 4 independent carrying springs or 2 longitudinal springs on the bogie, and at the same time either a central flat centre on the transverse support of the frame (French State) or on the bolster (Paris-Orleans, Paris-Lyons-Mediterranean). The Italian State Railway tenders with a volume of 22 m³ (777 cubic feet) have American bogies.

The spring gear of the carriages has been described in Part I-B/1.

2. To the extent to which the Administrations have given the sprung and unsprung weight of the different pairs of wheels of their steam locomotives, the ratio of the sprung weight of the bogies and of the trailing carrying pairs of wheels to their load on the rail varies from 0.84 to 0.9, whereas in the case of the axles driven by low-pressure cylinders and high-pressure cylinders respectively, this ratio is lower (0.7 to 0.77, and 0.73 to 0.8); for the other coupled wheels this ratio is between 0.74 and 0.81.

Table 2 gives for each locomotive the ratio of the total sprung weight to the total weight on the rail; it varies for the locomotives of all arrangements of coupled wheels between 0.76 (Rumanian State 230.000; Paris-Lyons-Mediterranean, 230 A) and 0.83 (French State, 231). An exception is the ratio of 0.7 of the Italian State locomotive No. 640.

In the case of the tenders the ratio is 0.84-0.89 for the 6-wheeled tenders, and 0.86-0.88 for the bogie tenders; in the case of the electric locomotives, 0.70-0.76, 0.80-0.84, and 0.75-0.81 in the different groups.

3. *a-b) The leading carrying wheels* of the steam locomotives are all less heavily loaded than the coupled wheels; the different Administrations follow no definite rules, but they point out that it is desirable that the leading bogies should carry a sufficient load for steady running and to prevent derailment, without it being necessary to sacrifice any part of the load required for adhesion on the coupled wheels.

Table 2 shows the ratio between the load on the bogie axle compared with the load on the coupled axle. The lowest ratio is found in the Belgian types 17 and 18 engines of English design, in which this ratio is 0.48 and 0.49. Most of the locomotives have a ratio of between 0.6-0.68; in the case of the Alsace-Lorraine locomotive 10, it is higher (0.93). In other words, the leading carrying wheels have an average of about 32 to 40 % (minimum 7, maximum 52 %) less load than the coupled wheels; there is no appreciable difference between the load on each of the coupled wheels in the locomotives we are dealing with. This is also the reason why the Administrations have not given any information as regards this reduction.

In the case of the *electric locomotives* the weight on the leading carrying wheels is less in the locomotives of the 2nd and 3rd groups only. The ratio of the load on the carrying axle to that of the driving axle reaches 0.57 (Italian State, E 326) and 0.83 (Paris-Orleans, 401); as an exceptional case it is also 0.93 in the Italian State, E 330, for a total load of 15 tons, and is 0.65 when the load

increases to 17 tons. In the case of locomotives with trucks the ratio in the case of the Paris-Orleans E 601 is 0.98 (maximum), and on the Paris-Lyons-Mediterranean 262 AE, the ratio is 0.7.

In the case of the Paris-Orleans engine No. 501, the axle load is reduced *gradually :* as regards the bogie axles the load on the extreme outside axle is reduced by 33 %, that on the inside pair of wheels only by 10.5 % relatively to the driving wheels, so that the shock of the guiding axle when entering on a curve shall be reduced and in order to prevent the trailing bogie from hunting on the straight line.

4. Most Administrations State that by suitable design and arrangement of the water tanks and coal bunkers there is but little reduction of axle loads as the water and coal are used up. In the case of the Paris-Orleans tender, however, the ratio of the sprung weight on the axle with the tanks empty to the maximum sprung weight, in a 6-wheeled type is 52, 32, 32 %, in the case of a bogie type 35.5, 56.5 %, which means that the load on the first pair of wheels as compared with the 2nd and 3rd is in the case of the 6-wheeled tender 63 % higher, and the weight on the second bogie as compared with the first 59 % higher. In the case of the 6-wheeled tenders of the Paris - Lyons - Mediterranean Railway, when loading the empty tender the weight per axle increases in the case of the leading axle by 16 % more than in the case of the trailing axle; in the case of the bogie tender on the contrary on the trailing bogie the load is 28 % more than on the leading pair of wheels; this is why a proportionally smaller load is placed on the leading axle of 6-wheeled-tenders and in the case of bogie tenders on the trailing bogie, so that when fully loaded the weight shall not differ appreciably from one pair of wheels to the other.

5. The height of the centres of gravity has not been given except by one or two Administrations so that it is impossible to make any deductions from the information supplied. The height of the centre of gravity of the locomotive as a whole as given varies between 1 700 and 1 900 mm. (5 ft. 7 in. and 6 ft. 2 13/16 in.), the corresponding height for the spring borne masses from 2 080 to 2 200 mm. (6 ft. 10 in. to 7 ft. 2 5/8 in.) the longitudinal height of the centre of the boiler of these locomotives is between 2 650 and 2 980 mm. (8 ft. 8 11/32 in. and 9 ft. 9 5/16 in.) above rail level.

The Paris-Orleans Railway avoids excessive oscillations of the locomotives by using stiffer springs for the coupled wheels in order to reduce the amplitude of the oscillations, especially when these springs are connected by longitudinal equalisers ; in addition, it does not make use of cross equalisers with centre bearings.

Furthermore, the Paris-Orleans uses the longest possible driving rod in order to reduce the vertical reactions of the rod end on the slide bars. In the case of tenders the Midi gives the height of the centre of gravity of the tender as a whole as 1 800-1 830 mm. (5 ft. 11 in. to 6 feet), and of the sprung mass as 1 950-1 970 mm. (6 ft. 4 13/16 in. to 6 ft. 5 9/16 in.).

As regards the height of the centre of gravity in the case of *electric locomotives,* it varies between the following limits : height of the centre of gravity of the whole engine 1 180-1 875 mm. (3 ft. 10 15/32 in. to 6 ft. 1 5/8 in), height of the sprung mass, 1 386-2 000 mm. (4 ft. 6 9/16 in. to 6 ft. 6 3/4 in.). In the case of the Paris-Orleans BB 101 locomotives, the body oscillations have been observed and recorded by means of Bowden wires and it has been found that these oscillations depend upon the rolling, as well as on the reactions at the rail joints.

6. The factor of safety, as determined by the Marié formula, is not given by any Administration. The different Administrations protect themselves against

the danger of broken springs either by using springs with a high factor of safety, or by limiting the play between the axle box and the frame, so that in the case of fracture of the springs on one side of the locomotive the inclination shall be as small as possible [on the Paris-Lyons-Mediterranean with a play of 25 mm (1 inch) the inclination is 1°15′ in the case of steam locomotives, and with 35 mm. (1 3/8 in.) an inclination of 56′ in the case of the electric locomotives].

III. — Adaptation of the running gear to irregularities in the superelevation and to differences in level of the track.

1. *What steps have been taken so that the different pairs of wheels, bogies, driving bogies, etc., shall run over defects in the level of the track, whether yielding or not, without danger as regards safety of running? What steps have been taken so that the engines can run over the superelevated rails without a dangerous reduction in the load on the wheels?*

2. *Have you checked in practice and by means of calculations the different types of the bogies, as regards their capability of adapting themselves to the helicoidal transition curves; what results have you obtained?*

3. *What is the design of carrying bogies and the bogies mainly assisting in getting good running on the straight and on curves, you consider as the most suited to run at high speeds with safety?*

The Railway Companies consider that it is desirable to counteract the unfavourable effect due to irregularities in the level of the track by carrying the locomotive on a bogie by means of a spherical support, by using springs connected together by equalisers, and possibly independent springs with sufficient deflection, and by maintaining sufficient vertical clearance between the axle boxes and the frame.

In the case of thoroughly well maintained lines these steps are obviously of less importance.

In order that each pair of wheels and the bogies shall behave properly when running over superelevated portions of line, i. e. when running over them without the weight on the wheels being reduced to a dangerous extent, the Administrations consider that the methods described above are sufficient.

It appears that the reduction of weight on the coupled wheels when running over the helicoidal surface of the superelevated line can be totally avoided only by using the Zara system axle boxes as used on the Italian State Railways, in which the faces of the axle-boxes are convex to a centre line parallel to the axis of the locomotive, these faces working in slides. This arrangement allows a coupled axle to place itself at an angle to another axle.

Systematic tests carried out with the bogies as regards the way they adapt themselves to the helicoidal surfaces of superelevated portions of line have not been carried out by any Administration.

To sum up, it may be said that the carrying bogies of present design, whether with centre bearing or with 2 side bearings with control gear, whether by horizontal laminated springs or by inclined helicoidal surfaces are suitable for high speeds with perfect safety.

IV. — Guiding of the vehicles and measures tending to improve the running on curves.

1. *Are you of the opinion that when guiding the locomotives by means of bogies the longitudinal centre line of the locomotive should be guided only by the centre of the leading bogie or of the motor bogie; or do you make the first coupled axle in the main frame take its part in guiding the engine?*

2. *What are the conditions of guiding on your electric locomotives with motor bogies? What is the ratio of the lateral*

static reaction to the load per axle or of the guiding wheels ?

3. *Have you obtained any figures or made any calculations concerning the value of the lateral dynamic forces due to the sudden angular action of the guiding wheels under shock ? What results have you found ?*

4. *What are you doing to keep the lateral reactions on the guiding wheels down to the minimum ?*

5. *By what methods do you arrive at the degree of safety against derailment ?*

6. *Have you made any experiments on the coefficient of friction of the wheels when sliding in the longitudinal and transverse directions ? What are the results ?*

7. *Do you lubricate the flanges of your guiding wheels ? If so please explain the design and arrangement of your lubricating devices.*

Or do you lubricate the inside face of the outside rail head on curves ? If so please give details of the process.

1. To the question should a locomotive only be guided by the bogie centre or should the first pair of wheels in the main frame also play its part in guiding the locomotive, most of the Administrations concerned think that the locomotive should be guided by the bogie centres only. They point out in particular that this prevents excessive wear of the flanges of this first pair of wheels by protecting it from lateral shocks which are harmful especially in the case of a crank axle.

Some Administrations point out that it is not always possible to prevent the leading coupled axle from taking part in guiding the locomotive; experiments show that the steady running of the locomotive is hardly affected. The French Est Railway prevents the leading coupled wheels from taking any part in guiding the locomotive by thickening the flanges of the bogie wheels from 32.5 to 37.5 mm. (1 9/32 in. to 1 15/32 in.) (Est 3100, 241000); in this way the transverse shocks are reduced as regards this axle which is a low pressure driving axle.

On some of the Italian State locomotives the first coupled axle is connected to the carrying axle (Italian bogie) and takes part in guiding the locomotive by moving laterally. In the case of the Paris-Orleans electric locomotives E 501 (2D2), it has been found that the leading motor axle takes part in guiding the locomotive with the bogie by setting itself to a curve of 500 to 600 m. (25 to 30 chains) radius. The Paris - Orleans locomotive E 401 (2D2) behaves in the same way when running into the curve; on a curve of over 200 m. (10 chains) radius, all the outside wheels tend to come into contact with the rails. The centering gear used on this class (fig. *a*, table 4) is based on this principle.

2. The Paris-Orleans Railway points out that the ratio of the lateral static reactions to the weight per axle is a maximum for the inside wheels of the 2nd driving pair wheels of the locomotive E 2D2 on a curve of a radius of 80 m. (4 chains); if we take the coefficient of transverse friction of 0.20, the ratio is approximately 1.3.

On the other hand the French State mentions that this ratio should be smaller than 1.

This fact should be proved on the one hand by the report of the Midi Railway, which shows that in the case of the motor bogies E 4601 the ratio : $\frac{1\,100}{19\,450} = 0.05$, and the report of the Paris-Lyons-Mediterranean, where the locomotive 262 AE has the ratio for the inside wheel : $\frac{\frac{3\,130}{2}}{5\,650} = 0.28$. The action of the centering device on the bogie centre, 3 130 kgr. (6 900 lb.) causes a reduction of the load on each inside wheel on the curve, of 600 kgr. (1 320 lb.) i. e. from

6 250 to 5 650 kgr. (13 780 to 12 460 lb.).

3. The value of the lateral dynamic forces caused by the sudden angular action of the guiding wheels under shock has not been measured. From calculations the Rumanian State Railways arrive at the lateral dynamic force for the locomotive 230000 as follows : *a)* Force due to the hunting of the locomotive on the first bogie axle 3 300 kgr. (7 270 lb.); *b)* force due to the movement on curves of 180 m. (9 chains) radius on the first bogie pair of wheels due to insufficient coning of the tyres, 1 685 kgr. (3 710 lb.); *c)* force due to each pair of bogie wheels running on curves of 180 m. (9 chains) radius, 3 900 kgr. (8 600 lb.); *d)* force due to each pair of wheels of the bogie running onto the curve 950 kgr. (2 090 lb.). The largest value of the lateral dynamic force caused by the guiding wheel (when entering a curve of the smallest radius) has been found to be 950 kgr. (2 090 lb.) for the carrying pair of wheels. This force is set at a speed of 45 km. (28 miles) per hour, i. e. 5 km. (3.1 miles) higher than the regulation speed on a 180-m. (9 chains) curve, and is much less at very low speeds and over transition curves.

The Paris-Orleans Railway has calculated the magnitude of the pressure of the guiding wheels and pressure produced on a straight line through the hunting of the Oerlikon electric locomotives. First of all the speed of the transverse deviation was calculated and this was found to be 5 cm. (2 inches) per second under an average action and 15 cm. (6 inches) per second when the action was severe. By means of special appliances (Mauzin system) the transverse deviations of the rails corresponding to these actions have been measured. The pressures have reached 4 to 5 tons when the deviation of the rails was approximately 6/10 mm. (0.0236 inch). Tests have been carried out with the locomotive EBB 101 at a speed of 90 km. (56 miles) per hour.

4. The reduction of the dynamic effects acting laterally on the rails is obtained in this sense that the locomotive is guided by the bogie centres and the initial tension on the centering device, which should be neither too great nor too small, has been properly selected. The Paris-Orleans hope to reduce these forces by not widening the gauge on curves in order to reduce the jarring of the leading wheels against the rails, especially at the moment of running onto the curve.

5. The Administrations endeavour to obtain safety against derailments by taking care, when building the locomotives, that the lateral reactions shall be as small as possible, by giving the bogie and axle box sufficient lateral movement, and by taking care that the reactions of the centering gear are proportional to the forces. It appears that the tendency to derailment can also be avoided by a suitable diameter of the guiding wheels [about 1 m. (3 ft. 3 3/8 in.)]. Some Administrations employ different methods (Belgium, Uebelacker; Italian State, Marié; Rumanian State, Barkhausen) for calculating theoretically the different reactions, the play needed and the curves that can be negotiated.

6. The coefficient of friction of the wheels sliding in the transverse direction has not been found by tests nor in any other way.

7. Some Administrations only lubricate the flanges of the guiding wheels, using different devices [Bouclon (French State); lubricant in tubes applied by hand (Midi); air injector (Italian State)], while other railways do not consider this necessary, either because they have no curves of small radius, or from the experience acquired they do not consider it of any use for locomotives for high speeds as these are always fitted with guiding bogies. The inside faces of the rail head are only greased in a few cases; most of these appear to be a ques-

tion of tests which have not resulted in the general introduction of the process.

V. — Details.

a) *Locomotives.*

1. *On what locomotives do you balance, in addition to the revolving parts not on the centre line, the reciprocating parts? What percentage of the static weight per wheel is the vertical component (free) of the centrifugal force for each wheel at the maximum running speed allowed?*

2. *How are the locomotive and the tender coupled together?*

3. *Do you use springs of different flexibility on the leading wheels, driving wheels and coupled wheels, as well as on the tender wheels? If yes or no, why? Have you made any experiments on the advantages or the disadvantages of more or less reducing the friction of the plates.*

4. *Please supply any information on the details of the arrangement and of the dimensions of the springs. (Dimensions of the springs, compression in mm. per ton, quality and characteristics of the spring steel, as well as the total flexion of each spring.)*

5. *What is the limit of wear allowed on the tread of tyres and on the flange?*

6. *What is the limit of wear allowed for the rails, especially the limit of lateral wear? Have the limits fixed in this respect been laid down as the result of experience or by other considerations?*

1. So far as the administrations have advised us, the reciprocating parts are balanced to the extent of 15 to 60 % of their weight. The free vertical component of the reciprocal force varies between the limits of 0 (Nord 4 cylinder locomotives, Czechoslovakian State 3 cylinder locomotives) to 19.5 (Midi) and 20 % (Egyptian). In most locomotives the maximum free centrifugal force is about 15 %.

2. The coupling between the locomotive and the tender in most cases consists of a coupling screw with 2 shackles and with special buffers on the Roy system (French State, Alsace-Lorraine, Midi, Paris-Orleans, Paris-Lyons-Mediterranean). Another coupling consists of a central coupling bar with screw and helical spring at the tender end (Belgian National, Egyptian State), and finally an entirely rigid coupling bar either with side buffers (Polish, Rumanian, Czechoslovakian State) or without buffers; in this last case the coupling is arranged as a cardan shaft (Est) or as a rod carried in a ball bearing universal joint (Italian 691), allowing both relative vertical movement of the tender and the locomotive as well as differences in inclination of one to the other.

3 and 4. Table 9 gives the dimensions and flexibility of the bearing springs of the bogies, coupled and carrying wheels of the steam locomotives. Laminated springs are used chiefly to carry the sprung weight and helical springs only in isolated cases (for the trailing carrying wheels of the Midi 3001, 3051; Paris-Orleans 3501, 4501; and Paris-Lyons-Mediterranean 231 D).

Some Administrations use springs with the same flexibility for all pairs of wheels (bogies, coupled and even the trailing carrying wheels); others, on the other hand, use springs of a flexibility inversely proportional to the weight on the wheels. Springs of high flexibility are used for the leading carrying wheels (Est 241000) in order to reduce the variation of the load on the guiding axles, and for the trailing carrying pair of wheels (bissel), in order to improve the springing of the locomotive under the cab and so reduce the fatigue of the enginemen.

As regards damping out the friction of the laminated springs, it is thought desirable to reduce the oscillations, and this is the reason why the Italian State Railways replaced the original helical

springs on the electric locomotive E 431 by laminated springs; the railways have not carried out any special trials in this respect.

The tensile strength of the spring steel varies between 70 and 85 kgr./mm² (44.4 to 53.97 Engl. tons per sq. inch), for the steel before hardening, and 110 to 145 kgr./mm² (69.8 to 93 Engl. tons) per sq. inch) for the hardened steel. On the French Railways the elongation of spring steel must be at least 0.008. The railways obtain these steels to specifications Nos. 8 and 10. (Cfr. *Bulletin of the Railway Congress*, January 1922, p. 240.)

5. According to the returns received the limit of wear allowed on the tread and on the flange is different on nearly every railway whether it is a question of returning or of condemning the tyres. The different administrations require the tyres to be turned in the case of locomotives when the wear on the tread reaches a give amount or when the tyre flange has been reduced in thickness to a certain limit, or when the height of the flange reaches a given figure, or finally when the flats on the tread reach a certain depth. In the first case the wear on the tread in depth is usually 3 mm. (1/8 inch) (Paris-Lyons-Mediterranean) to 5 mm. (13/64 inch) (Belgian National, Midi, Paris-Orleans, Italian State); the minimum thickness of the flange varies between 10 mm. (3/8 in.) (Midi, section No. 15 of table 5), 14 mm. (9/16 in.) (Belgian National, section No. 5); 18 mm. (11/16 in.) (Belgian National, other sections); 20 mm. (25/32 in.) (Jugoslav State, Alsace-Lorraine); 22 mm. (7/8 in.) (Polish State); 22.5 (15/16 in.) (Paris-Orleans, section No. 19, Nord, section No. 17) ; 24.5 (31/32 in.) (Nord, section No. 16 for tyres other than bogie tyres), 25 mm. (1 inch) (French State), 26 (1 1/32 in.) (Midi, section No. 14), 26.5 mm. (1 3/64 in.) (Est, section No. 11), 28.5 mm. (1 1/8 in.) (Nord, section No. 16 for bogie wheels), and 31.5 mm. (1 1/4 in.) (Est, section No. 10). The depth of flange must not exceed 35 mm. (1 3/8 in.) (French State), and 36 mm. (1 7/16 in.) (Polish State, French State, Paris-Orleans, section No. 19). Some administrations also turn the flange as soon as the radius of the curve at the root is less than for example, Paris-Orleans 8 mm. (5/16 in.), Italian State 11.5 mm. (15/32 in.). The Paris-Lyons-Mediterranean Railway turns up the tyres to the original section, but with the flange slightly thinner (29, 24, 20.5 mm. (1 9/64 in., 15/16 in. and 13/16 in.), instead of 32.5, 27.5 and 22.5 mm. (1 9/32 in., 1 3/32 in. and 29/32 in.), to avoid reducing the thickness of the tyres too much. In the same way some Administrations lay down certain lower limits when turning the tyres; if these limits have not been reached when the tyre is turned, the tyres are allowed to go into service until they wear down to the limits laid down at which they must be withdrawn from service.

The minimum thickness of the tyre decides when it shall be withdrawn from service; this thickness is fixed at different values by each railway :

30 mm. (1 3/16 in.) [Nord carrying wheels, Paris-Orleans carrying wheels, Jugoslav State, Polish State, Alsace-Lorraine, Belgian National tyre fastening other than the Caledonian].

32 mm. (1 1/4 in.) (Nord, coupled wheels; Est, standard).

35 (1 3/8 in.) [Belgian National, Caledonian fastening; Paris-Lyons-Mediterranean for wheels larger in diameter than 1 300 mm. (4 ft. 3 3/16 in.); French State, Rumanian State (carrying wheels)].

40 mm. (1 9/16 in.) [Midi, Paris-Orleans coupled, Paris-Lyons-Mediterranean for wheels larger in diameter than 1 300 mm. (4 ft. 3 3/16 in.), Rumanian State, coupled wheels].

43 mm. (1 11/16 in.) (Est thickened flanges).

On the Paris-Lyons-Mediterranean Railway the tyres are withdrawn from serv-

ice when their width is less than 135 mm. (5 5/16 in.).

b) *Carriages and wagons.*

1. *Please give information on the details of the arrangement, position and dimensions of the springs (dimension of the springs, compression in mm./t., quality and maximum tensile of the spring steel), in particular on the total deflection with the vehicle empty as well as loaded.*

2. *Have you investigated the oscillation of the springs under load, on a stationary and also on a moving vehicle ?*

3. *Have you made any measurements of the oscillations of the wagons and carriages, or of the bodies of the wagons and carriages in the direction of the longitudinal axis, lateral axis and the vertical axis ? How and by means of what apparatus have you made these measurements and what results have you obtained ?*

4. *Do you use rubber or other special materials to damp out the oscillations and noise ?*

5. *What is the length of the screw coupling lever used on the carriages and wagons ? How many mm. can the buffers be compressed by means of these screw couplings and what is the resulting compression, in kgr., between the wagons ?*

6. *Supply particulars of the design of the bolsters, on the arrangement and details of the bolster swing links, on the method of supporting the body on the bogies (centres with balls, stepped centres, friction blocks, etc.).*

The spring gear of the bogies has been dealt with in Part I-B.

Laminated springs, both above the axle boxes and on the bolsters, are generally used on the « International » type, whereas on the « Pennsylvania » type, helical springs are chiefly used between the bogie frame and the equaliser resting on the axle boxes.

The principal dimensions of the *bogie springs* are given in table 6.

The *flexibility* per ton in the case of passenger carriages with elliptical springs (on the bogie as a whole) is 3 to 8 mm. (1/8 to 5/16 in.), the helical carrying springs (on one side) 5.9 to 9.7 mm. (15/64 to 3/8 in.), the separate laminated bearing springs 14 to 26.9 mm. (35/64 to 1 1/16 in.) and finally in the case of the auxiliary springs on the spring hangers 12 to 16.5 mm. (15/32 to 1 5/32 in.).

A systematic measurement of the transverse oscillations of the body at high speeds is being carried out by some Railway Companies in collaboration with the Technical Committee of the U.I.C. (Union Internationale des Chemins de fer) and promises to give interesting and useful information.

The Railways also endeavour to reduce the noise in the carriages by welding the floor plates, and by covering them over with a second wood floor or with a layer of cork. The floor and the walls are lined with wood, laths covered with cloth being placed between the outside sheeting and the wood lining, or the plates are covered with cloth or cork (Est, Paris-Lyons-Mediterranean).

Some Railways insert a layer of wood between the body side plating to insulate the vehicle against noise and variations in temperature (Czechoslovakian State).

Indiarubber is used in isolated cases in the buffing and draw gear to avoid too sudden reactions (Est).

The length of the screw coupling lever is usually 230 to 380 mm. (9 1/16 to 14 15/16 in.), and most often is between 300 and 320 mm. (11 13/16 to 1 9/16 in.), the compression of the buffers is 10 to 45 mm. (3/8 to 1 49/64 in.) representing a force from 2 500 to 3 400 kgr. (5 500 to 7 500 lb.).

The bolster is built up of rolled sections, of pressed plates or cast steel. In many cases it is covered with wood to deaden the noise.

I	TYPE OF LOCOMOTIVE.		Wheel arrangement.	Maximum speed, km./hour.	Diameter of wheels.	Length over buffers.	Distance between motor bogie centres.	Distance between wheel centres.		
								I-II	II-III	III-I
					← Millimetres					
Two four-wheeled motor bogies.	French Midi	4601	BB	90	1 400	12 870	6 000	2 950	3 050	2 95
	Paris-Orleans.	EBB 1-80	BB	90	1 250	12 690	6 100	2 700	3 400	2 70
		EBB 101-180	BB	95	1 350	12 580	5 940	2 800	3 140	2 80
		EBB 225-240	BB	90	1 350	12 754	5 700	2 800	2 900	2 80
	French State	Locomotor	BB	110	1 200	12 140	6 100	2 700	3 400	2 70

II	TYPE OF LOCOMOTIVE.		Wheel arrangement.	Maximum speed, km./hour.	Diameter of carrying / driving wheels.	Length over buffers.	Distance between bogie centres.	Dista	
								bogie	bogie wheel and fi couple
					← Millimetr				
Driving wheels in the main frame and carrying bogies.	French Midi	3101	2C2	120	900/1 750	14 500	9 200	2 000	1 60
	Paris-Orleans	501, 502	2D2	120	970/1 750	17 780	11 450	2 400	1 80
		401, 402	2D2	120	970/1 750	16 040	13 840	2 200	1 57
	Italian State	E 330	1C1	100	950/1 630	10 990	...	...	2 40
		E 332	2C2	100	960/1 630	13 370	8 600	2 000	1 50
		E 431	1D1	100	1 110/1 630	14 510	...	...	2 60
		E 432	1D1	100	1 110/1 630	13 910	...	...	2 40
		E 326	2C2	130	1 110/ ?	16 300	14 100	2 200	1 90

III	TYPE OF LOCOMOTIVE.		Wheel arrangement.	Maximum speed, km./hour.	Diameter of carrying / driving wheels.	Length over buffers.	Distance between body centres.	Distance betwe			
								Motor truck			
								bogie.		driving.	
					← Millimetr						
Two motor trucks.	Paris-Orleans	E 601	2CC2	105	970/1 200	18 950	9 830	2 000	2 260	1 425	1 42
	P.-L.-M.	262 AE	2CC2	?	1 010/1 600	23 800	15 288	2 100	2 000	2 300	2 30

ocomotives. TABLE I.

Total wheel base.	Axle load, in metric tons. I	II	III	IV	Total weight, in metric tons.	Total sprung weight, in metric tons.	Sprung weight / Total weight.
8 950	4 × 19.45				77.8	59.2	0.76
8 800	4 × 17.3				69.2	49.3	0.71
8 740	4 × 18.27				73.07	51.76	0.71
8 500	4 × 18.7				74.8	55.2	0.74
8 800	4 × 15.65				62.6	43.64	0.7

etween wheel centres. driving. I-II	II-III	III-IV	bogie.	Total wheel base.	Axle load, in metric tons. bogie.		driving.				bogie.		Total weight, in metric tons.	Total sprung weight, in metric tons.	Sprung weight / Total weight.
2 000	2 000	...	1 600	2 000	11 200	11.5	11.5	18	18	18	...	11.5	11.5	100	83.9	0.84
1 850	2 050	1 850	1 800	2 400	14 150	12	14.5	18	18	18	18	14.5	12	125	104.5	0.83
1 850	1 850	1 850	1 575	2 200	13 100	14.93	14.93	18	18	18	18	14.93	14.93	131.72	107.24	0·82
1 800	1 800	...	2 400	...	8 400	...	11	17	17	17	...	11	...	73	...	...
						...	14	15	15	15	...	14				
1 800	1 800	...	1 500	2 000	10 600	11.2	11.2	16	16	16	...	11.2	11.2	92.8	...	...
1 710	2 350	2 350	2 600	...	11 610	...	13	16	16	16.5	16.5	13	...	91	72.6	0.8
1 710	2 100	2 100	2 400	...	10 700	...	13.5	16.7	16.8	16.8	16.7	13 7	...	94	75.3	0.8
2 500	2 500	...	1 900	2 200	13 200	12	12	21	21	21	...	12	12	111	89.5	0.81

heel centres. Be-tween rucks.	Motor truck bogie.		driving.		Total wheel base.	Axle load, in metric tons. bogie.	driving.	bogie.	Total weight, in metric tons.	Total sprung weight, in metric tons.	Total weight / Total sprung weight.
1 980	1 425	1 425	2 260	2 000	16 200	2×12.45	6×12 7	2×12.45	126	94	0.75
3 400	2 300	2 300	2 000	2 100	20 800	2×12.5	6×18	2×12.5	158	128.1	0.81

Wheel arrangement.	Type of locomotive.	Wheel base, in millimetres								Rigid wheel base. / Total wheel base.	Guided length (mm.).
		bogie.	between carrying axle and first coupled pair of wheels	of the pairs of coupled wheels			between fourth pair of coupled wheels and carrying pair	total.	rigid.		
				I-II	II-III	III-IV					
4-4-0	Belgian National Ry. Co. 17	1 981	2 236	2 744	...	...	...	7 035	2 744	0.39	6 046
	18	»	2 311	2 895	...	...	. .	7 187	2 895	0.40	6 197
	20	2 250	2 500	2 895	...	...	...	7 645	2 895	0.38	6 520
	66	2 200	2 800	3 000	...	...	...	8 000	3 000	0.37	6 900
4-4-2	6	2 250	1 850	2 090	...	...	2 450	8 640	2 090	0.24	5 065
	69	2 200	2 350	2 300	...	. .	3 900	10 750	2 300	0.21	5 750
	French Nord 2643	2 100	1 850	2 150	...	...	2 400	8 500	4 550	0.53	7 450
	Paris-Orleans 3001	2 300	1 750	2 150	...	...	2 500	8 700	4 650	0.53	7 550
	Egyptian State	2 134	2 045	2 083	...	..	3 200	9 462	2 083	0.22	5 195
4-6-0	Belgian National Ry. Co. 7	2 250	1 880	2 000	2 750	...	...	8 880	4 750	0.53	7 755
	9	»	2 200	2 060	2 200	...	...	8 710	4 260	0.49	7 585
	Alsace-Lorraine S 10[1]	2 200	2 200	2 100	2 600	...	...	9 100	4 700	0.51	8 000
	French Est 3100	2 100	1 840	2 200	2 750	...	...	8 890	4 950	0.56	7 840
	Midi 3501	2 300	2 100	2 000	2 700	...	...	9 100	4 700	0.52	7 950
	Paris-Orleans (1715 / 3201)	2 100	2 000	2 150	2 250	...	...	8 500	4 400	0.52	7 450
	4001	2 300	1 750	2 000	2 200	...	...	8 250	4 200	0.51	7 100
	P.-L.-M. 230 C	2 000	1 935	1 920	2 680	...	...	8 535	4 600	0.54	7 535
	230 A	2 000	1 955	1 830	2 100	...	...	7 885	3 930	0.50	6 885
	Italian State 671	2 350	1 750	2 050	2 050	...	...	8 200	4 100	...	6 900
	Polish State OK 22	2 200	1 570	1 880	2 700	...	...	8 350	4 580	0.55	7 250
	Rumanian State 230000	2 200	1 570	1 880	2 700	...	...	8 350	4 580	0.55	7 250
4-6-2	Belgian National Ry. Co. 10	2 050	1 675	2 050	2 050	...	3 600	11 425	4 100	0.36	6 800
	French State 231	2 300	1 700	2 050	2 050	...	2 800	10 900	4 100	0.37	6 950
	Alsace-Lorraine S 14	2 300	1 700	2 050	2 050	...	2 800	10 900	4 100	0.37	6 950
	French Est 31000	2 300	1 700	2 050	2 050	...	2 800	10 900	4 100	0.37	6 950
	Midi (3001 / 3051)	2 300	1 700	2 050	2 050	...	2 600	10 700	4 100	0.38	6 950
	3101	2 300	1 550	2 050	2 050	...	2 700	10 650	4 100	0.38	6 800
	French Nord 31251	2 300	1 850	2 010	2 010	. .	2 250	10 420	4 020	0 39	7 020
	Paris-Orleans 3501	2 300	1 700	2 050	2 050	...	2 600	10 700	4 100	0.38	6 950
	3591	2 300	1 524	2 032	2 032	. .	3 280	11 168	4 064	0.36	6 738
	3641	2 300	1 700	2 050	2 050	...	2 800	10 900	4 100	0.37	6 950
	4501	2 300	1 700	1 950	1 950	...	2 600	10 500	3 900	0.37	6 750
	P.-L.-M. 231 D	2 300	1 700	2 100	2 100	...	3 030	11 230	4 200	0.37	7 050
	Italian State 691	2 100	1 650	2 150	2 150	...	2 900	10 950	4 300	...	7 000
	Rumanian State 231000	2 100	1 470	1 950	1 950	...	3 700	11 170	3 900	0.35	6 420
	Jugoslav State	2 500	1 750	2 100	2 100	...	2 200	10 650	4 200	...	7 200
	Czechoslovakian State 3870	2 300	1 600	2 050	2 050	...	3 000	11 000	4 100	0.37	6 850
4-8-0	Polish State Os 24	2 440	1 550	1 850	1 850	1 850	...	9 540	3 550	0.37	8 270
4-8-2	French Est 241000	2 100	1 650	2 050	2 050	2 050	3 270	13 170	6 150	0.47	8 850
	Polish State Pu 29	2 100	1 500	2 000	2 000	2 000	3 600	13 200	6 000	0 45	8 500
2-6-0	Italian State 640	...	* 2 550	1 950	2 250	...	...	6 750	2 250	0.34	...
2-6-2	685	...	* 2 500	2 000	1 950	...	2 000	8 450	1 950	0.23	...
2-8-2	746	. .	* 2 600	1 980	1 980	1 980	2 700	11 240	3 960	0 35	...

* Italian bogie.

TABLE 2.

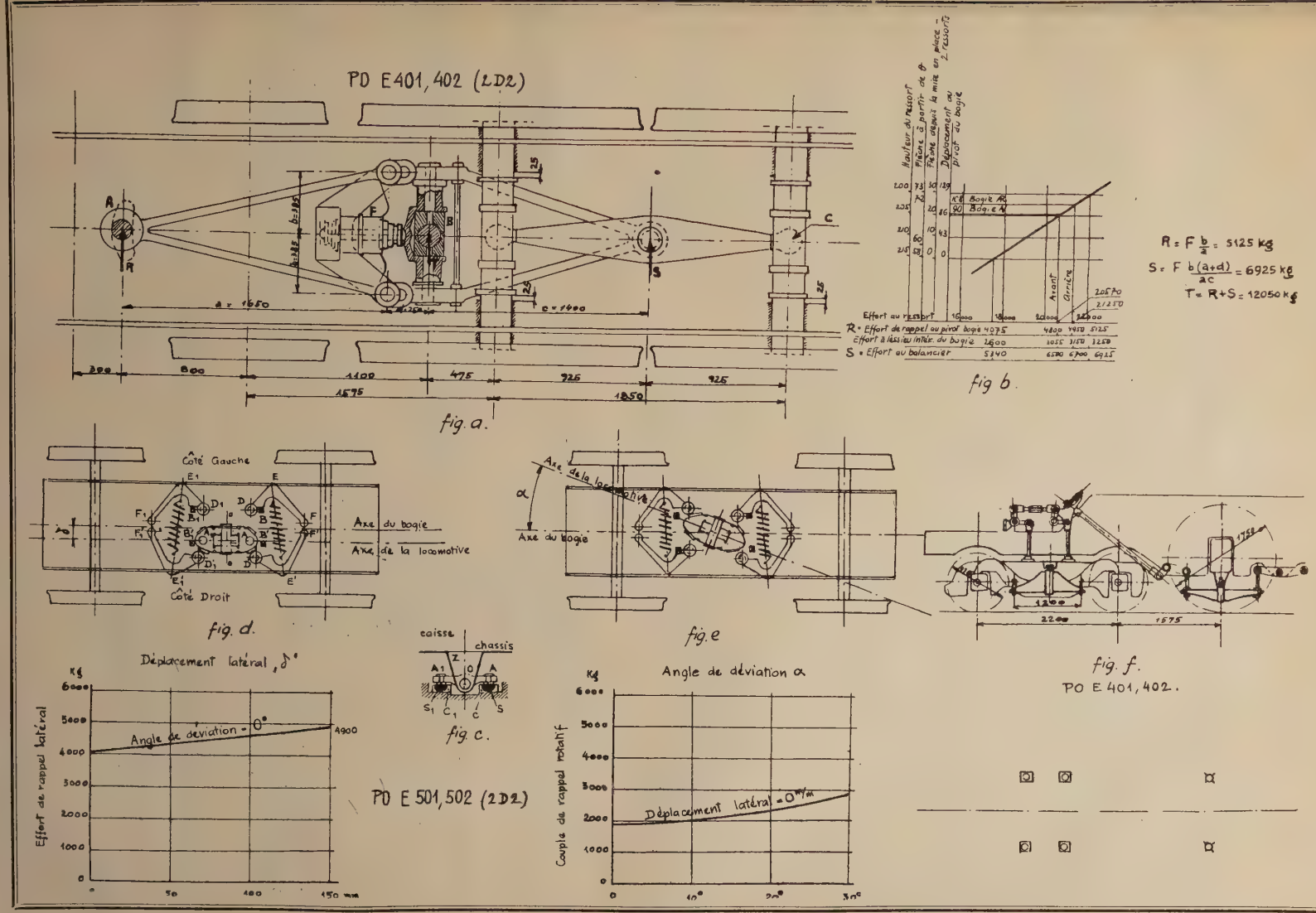
Axle load, in metric tons							Total weight in working order, in metric tons.	Axle load bogie / motor.	Total sprung weight, metr.-tons.	Total sprung weight / Total weight in working order.	Length of radius rod of carrying pair of wheels, in mm.	Side movement ± mm. Thickness of flange reduced ⊥ mm.				
bogie		coupled				carrying.						Bogie centre.	Coupled wheels			Carrying pair of wheels.
1	2	I	II	III	IV								I	II	III	IV	
17.40		17.73	17.30	...	...	...	52.43	0.49	...	...	...	19	⊥ 7.5	...	...	...	...
8.70	8.35	18.30	18.00	...	...	...	53.35	0.48	...	...	...	19	⊥ 7.5	...	...	...	...
1.00	11.00	18.60	18.30	...	...	...	58.90	0.59	...	...	...	35	⊥ 7.5	...	...	...	...
3.30	13 30	17.50	17.50	...	...	...	61.60	0.71	...	...	...	40	⊥ 5	...	...	...	...
9.90	9.90	18.60	18.30	...	...	17.80	74.50	0.53	...	...	...	40	...	⊥ 7.5	...	...	...
2.50	12.50	16.50	16.50	...	...	16.50	74.50	0.76	...	...	...	50	⊥ 5	...	...	...	37
9.50	9.50	18.50	18.50	...	...	14.00	70.00	0.51	56.60	0.81	...	55	⊥ 2	⊥ 19.5	...	...	...
0.40	10.40	18.00	18.00	...	...	17.20	74.00	0.58	58 80	0.80	...	45	⊥ 4 3	⊥ 16.4	...	..	...
23.90		17.90	18.60	...	..	17.70	77.50	0.63	62.90	0.81	...	50	...	...	...	...	6.35
1.94	11.81	19.82	19.98	19 92	...	...	83.47	0.60	...	...	...	80	...	⊥ 7.5	...	...	...
4.00	14.00	18.30	18.00	17.00	...	...	81.30	0.76	...	...	...	80	...	⊥ 7.5	...	...	...
32.20		17.36	17.32	17 31	...	...	84.19	0.93	69.20	0.77	...	40	...	⊥ 15	...	...	...
24.70		17.90	18 40	18.40	...	...	79.40	0.67	61.50	0.78	...	55	⌋ 5.3	⊥ 5 3	...	...	...
1 50	11.50	18.00	18.00	18.00	...	...	76.30	0.62	61.50	0.81	...	50	...	⊥16.25	...	..	...
9.50	9.50	16.50	16.70	16.60	...	..	68.80	0.57	53.70	0.78	...	45	...	⊥ 16.4	...	...	...
0.35	10.35	18 20	18.20	18.20	...	...	75.30	0.57	58.90	0.78	...	45	⊥ 4 3	⊥ 16 4	...	..	...
1.25	11.25	16.98	16.99	16.99	...	...	73.46	0.66	58.30	0.79	...	38	...	⊥ 10	...	..	..
8.68	8.68	14.45	14.45	14.45	...	..	60.71	0.60	45.80	0.76	...	38	...	...	16	...	...
2.00	13.80	15.80	15.80	15.80	...	...	73 20	0.76 / 0.87	...	...	...	50	...	...	10	...	...
4.00	14.00	17 00	17.00	17.00	...	...	79.00	0.82	60.80	0.77	...	40	...	⊥ 15	...	...	...
23.00		16.92	16.90	16.66	...	...	73.48	0.68	55.60	0.76	...	40	...	⊥ 15	...	...	...
2.00	12.00	22.40	22.40	22.20	...	22.00	113.00	0.53	...	...	...	65	...	⊥ 7.5	...	...	75
22.70		19.00	19.10	19.20	...	17.75	97.75	0.59	80.70	0.83	1 575	60	...	...	...	...	...
23.40		18.60	18.50	18.60	...	17.40	96.50	0.63	77.60	0 80	1 575	60	...	...	...	...	75
23.60		18.40	18.50	18.50	...	17.80	96.80	0.64	76.90	0.80	1 575	**60	...	...	...	...	92
0.70	10.70	18.00	18.00	18.00	...	14.60	90.00	0.60	71.10	0.79	...	50	...	⊥16.25	.	...	45
1.15	11 15					15.00	91.30	0.62	72.40	0.79							
0.25	10.25	18.00	18.00	18.00	...	14.60	89 10	0.57	70.40	0.79	1 985	50	...	⊥16.25	..	..	50
5.60	15 60	19.00	19.00	18.80	...	12.50	100.50	0.82	82.20	0 82	...	65	⊥ 2	⊥ 19.5	...	...	85
1.60	11.60	17.65	17.65	17.65	...	16.65	92.80	0.66	73.10	0.79	...	45	⊥ 4.3	⊥ 16.4	...	...	46
1.30	11.30	17.85	17.85	17.85	...	17.15	93.30	0.63	72.70	0.78	1 975	83	...	⊥ 16.4	...	...	61
1.30	11.30	18.80	19.00	18.80	...	16.90	96.10	0.60	74.90	0.78	1 575	60	...	⊥ 4 3	...	...	75
1.21	11.21	17.44	17.44	17 44	...	15.20	89.94	0.64	71.20	0 79	...	45	⊥ 4.3	⊥ 16.4	...	...	46
1.00	11.00	18.50	18 50	18.50	...	16 50	94.00	0 60	73.00	0.78	1 900	60	...	⊥ 10	. .	...	66
10 00	10.00	18.00	18.00	18.00	...	16.50	90.50	0.56	71.10	0.79	2 350	40	...	⊥ 7	...	..	25
27 26		16.85	17.17	16.90	...	14.50	92.68	0.79	75.20	0.81	...	60	. .	⊥ 7	...	...	60
4.37	14.37	17 55	17.55	17.55	...	16 60	97.99	0.82	74 80	0.77	...	...	...	⊥ 10	...	...	...
1.20	11.50	16.60	16.70	16.90	...	16.70	89.60	0.66	70 60	0.79	...	80	...	⊥ 10	. .	...	60
13.00	14.00	15.80	15.80	15.80	15.80	...	90.20	0.82 / 0.88	71.10	0.79	...	40	...	⊥ 8	...	26	...
25.18		18 80	18.60	18.50	18.80	17.30	117.18	0.67	91.70	0.78	2 400	**125	⊥ 12 3	⊥ 6.8	⊥ 6.8	⊥ 1.5	150
11.00	11.00	18.00	18.00	18.00	18.00	17.00	111 00	0 61	85.50	0.77	2 300	100	...	...	30	...	100
...	10.50	14.60	14.70	14.70	...	...	54.50	0.71	42.30	0 70	...	30	10	...	...	...	...
...	11 20	15.60	15.80	15.50	...	14.00	72.10	0.70	...	...	...	45	10	...	...	...	10
...	13.00	16.20	16.20	16 20	16 20	16.00	93.80	0.80	...	...	2 150	20	...	...	...	...	60

** Flange thickened + 5 mm.

Centering gear on steam locomotives.

TABLE 3.

Type of locomotive.		Wheel arrangement.	How carried on the bogie.	Centering force in kgr. initial.	Centering force in kgr. final.	Design of the control springs. Number of leaves.	Design of the control springs. Cross section, in mm.	Design of the control springs. Flexibility, in mm./met.ton.	*Remarks.*
A) *Control by laminated springs :*									
Belgian National Ry Co.	66	4-4-0	Plain side bearings.	1 200	3 600	...	...	...	...
	69	4-4-2		1 700	5 533	...	...	..	..
Egyptian State		4-4-2		...	...	6	88.9×15.9	...	...
Alsace-Lorraine	S 10-1	4-6-0		3 600	7 300	4	90×13	10.7	...
Rumanian State	230000	4-6-0		3 000	7 800	4	90×13	...	...
Polish State	Pu 29	4-8-2		450	3 480	5	90×13	...	...
	Ok 22	4-6-0		909	4 545	4	90×13	...	...
French Est	241000	4-8-2		6 940	...	16	90×12	9.8	With helical
French Midi	3501	4-6-0		4 000	7 100	13	75×10	8.3	springs, diam.
	3001	4-6-2	Spherical side bearings.	4 000	7 100	13	75×10	8.3	30 mm., flex. 20.3.
	3051								
	3101	4-6-2		4 000	7 100	13	75×10	8.3	...
Rumanian State	231000	4-6-2		1 250	5 000	6	100×10	...	...
Polish State	Os 24	4-8-0		1 225	5 528	7	90×10	...	...
French Est	3100	4-6-0	...	1 785	5 715	11	75×10	7	...
French Nord	31251	4-6-2	...	2 200	5 900	...	...	...	...
Czechoslovakian State	3870	4-6-2	Spherical centre.	1 125	...	7	90×10	11.5	...
Jugoslav State	—	4-6-2	...	..	...	...	...	...	...
B) *Control by helical springs :*									
Belgian National Ry Co.	17	4-4-0	Plain centre bearings.	0	4 200	...	...	..	..
	18	4-4-0		0	4 200	...	...	...	..
French Nord	2643	4-4-2		4 000	9 500	...	...	...	...
Paris-Orleans	3001	4-4-2	Spherical side bearings.						
	4001	4-6-0		4 500	9 000	...	...	...	...
	3501	4-6-2							
	4501	4-6-2							
C) *Control by inclined planes :*									
P.-L.-M.	231D	4-6-2	Spherical centre.	4 004	4 519	..	...	...	...
	230C	4-6-0		280	23	...	...	...	..
	230A.M	4-6-0		295	23	...	...	...	...
D) *Control by bolsters :*									
Belgian National Ry Co.	20	4-4-0	Spherical centres.	0	3 680	...	...	...	...
	6	4-4-2		0	3 315	...	...	...	...
	7	4-6-0		1 480	5 450	...	...	..	Triangular swing links.
	9	4-6-0		0	5 540	...	...	...	...
	10	4-6-2		0	4 875	..	..	...	..
Paris-Orleans	1715	4-6-0		2 850	6 000	...	...	...	
	3201								Triangular swing links.
	3591	4-6-2	Plain centre bearings.	4 430	8 880	...	...	...	
	3641	4-6-2		0	8 880	...	...	...	...
French State	231	4-6-2		0	9 500	...	...	...	...
Alsace-Lorraine	S 14	4-6-2		0	10 500	...	...	...	...
French Est	31000	4-6 2		...	...	...	...	...	..
E) *Control by bolsters and volute springs :*									
Italian State	671	4-6-0	Plain centre bearings.	1 800	2 800	...	...	...	...
	691	4-6-2		2 000	3 000	...	...	...	...



Explanation of French terms, etc.:

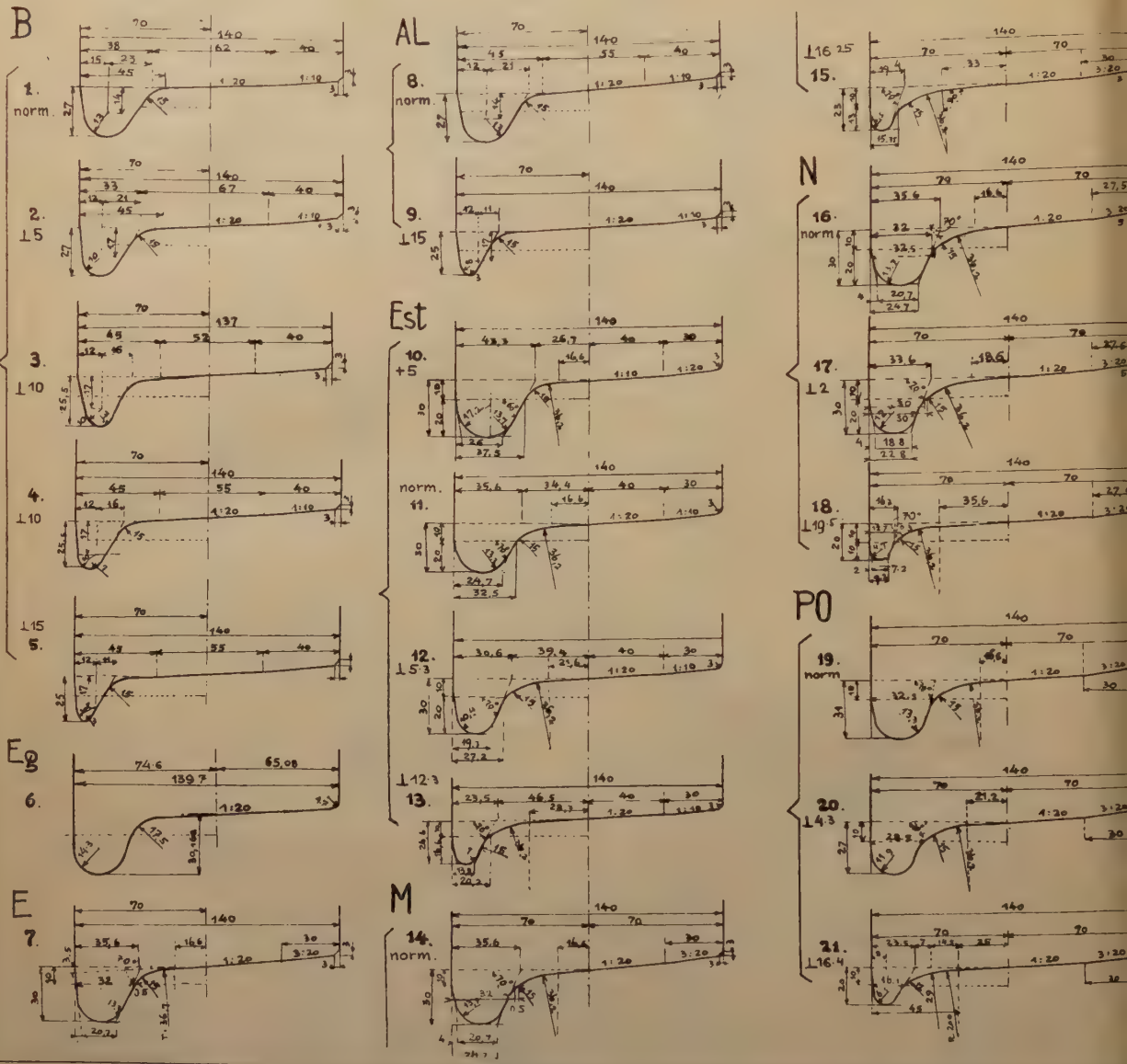
Fig. a) P. O. = Paris-Orleans Railway.

Fig. b) Hauteur du ressort = Height of the spring. — Flèche à partir de... = Deflection starting from... — Flèche depuis la mise en place (2 ressorts) = Deflection starting with springs in position (2 springs). — Déplacement au pivot du bogie = Side movement at bogie centre. — Effort au ressort = Load on the spring. — Effort de rappel au pivot bogie = Centering force at bogie centre. — Effort à l'essieu intér. du bogie = Force at inner pair of wheels of the bogie.

Fig. c) Caisse = Body. — Châssis = Frame. — Couple de rappel rotatif = Centering couple round centre. — Angle de déviation = Angle of deviation. — Déplacement latéral = Side movement. — Effort au balancier = Force at the equalising lever.

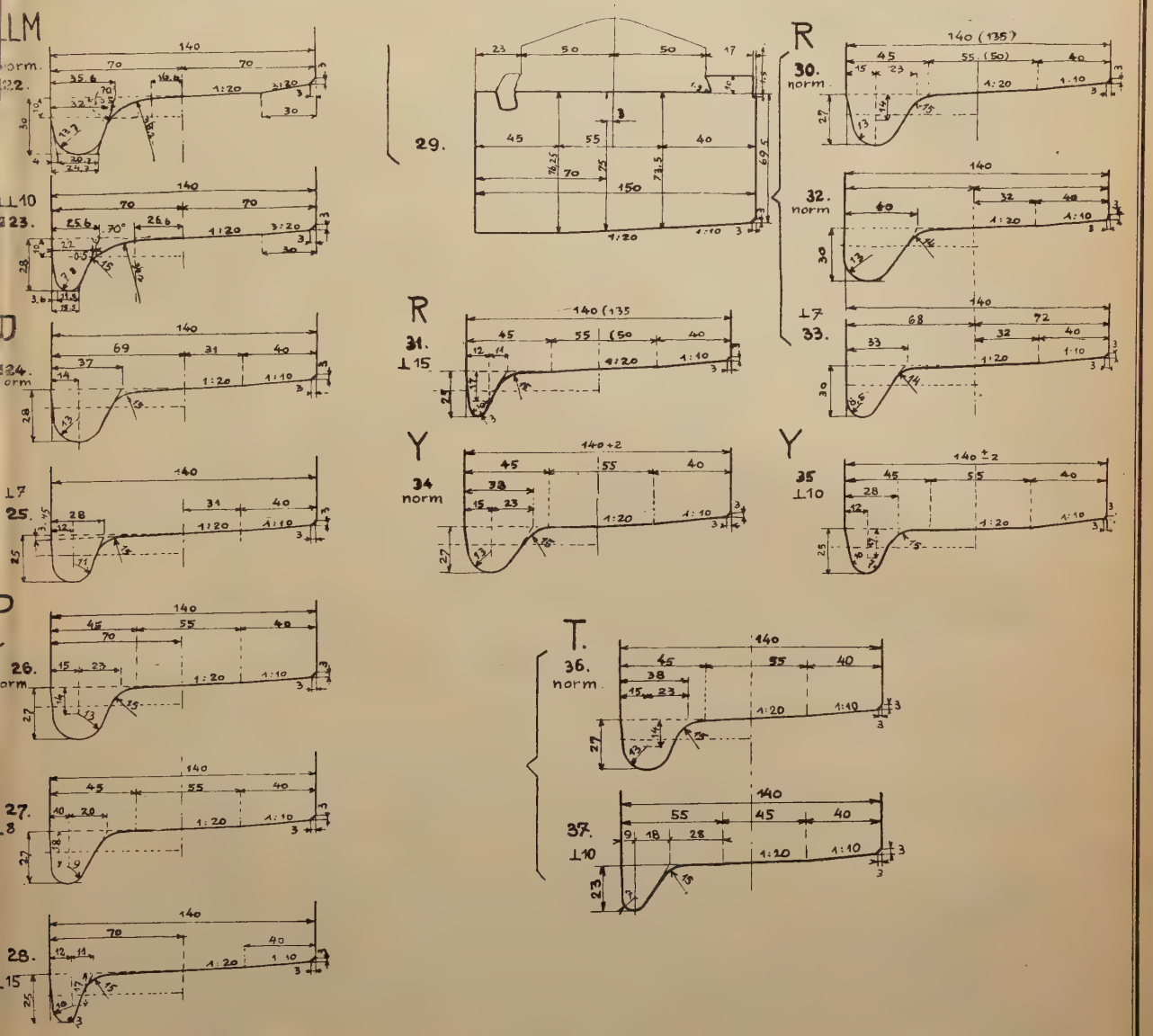
Fig. d) Côté gauche = Left side. — Côté droit = Right side.

Figs. d) **and e**) Axe du bogie = Bogie centre line. — Axe de la locomotive = Engine centre line. — Effort de rappel latéral = Side centering force. — Déplacement latéral = Side movement. — Angle de déviation = Angle of deviation.



AL = Alsace-Lorraine.
B = Belgian National Railway Company.
PLM = Paris-Lyons-Mediterranean.
N = Nord.

Est = Est.
T = Czechoslovakian State.
PO = Paris-Orleans.
P = Polish State.



Eg = Egyptian State.
E = French State.
M = Midi.
R = Rumanian State.

Y = Jugoslav State.
I = Italian State.
norm. = standard.

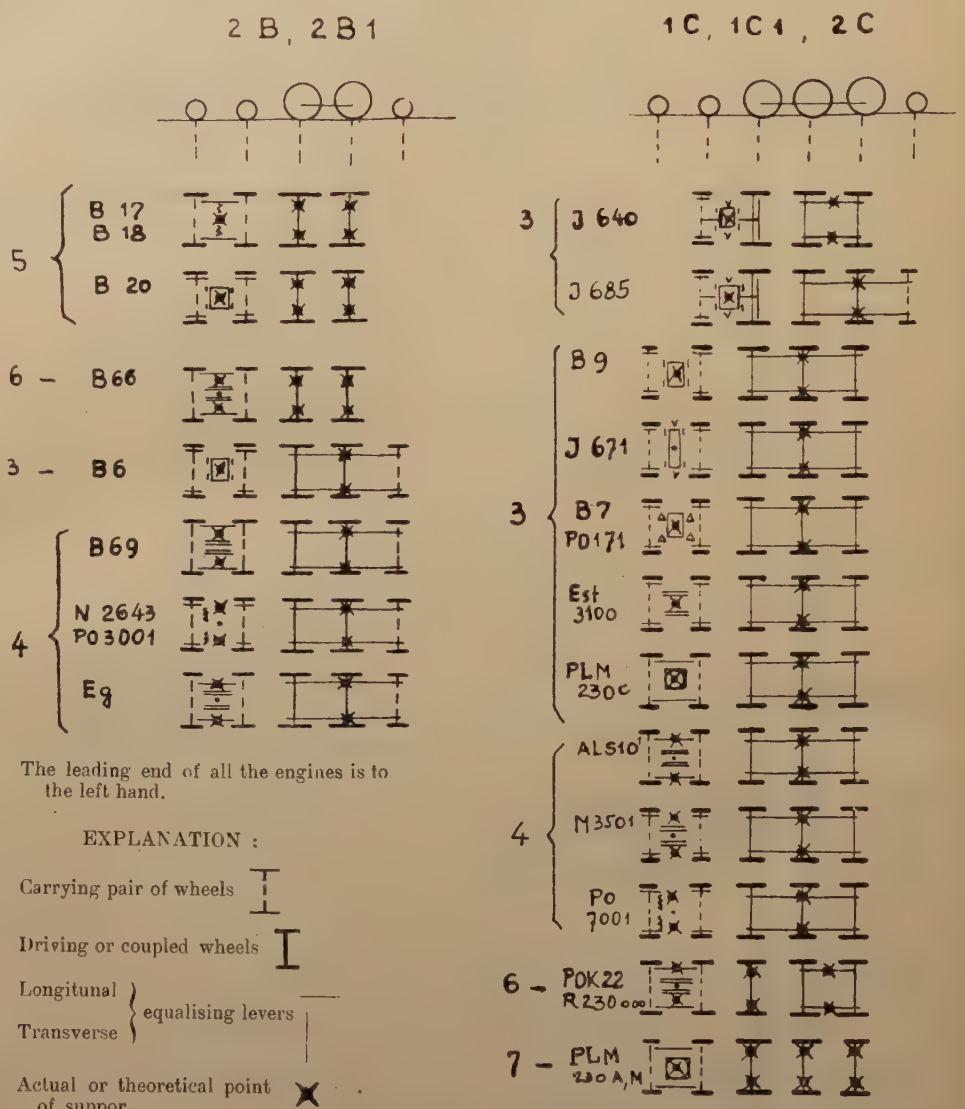
Name of Administration.	Type.	Length over buffers	Wheel base of bogies.	Distance between body centres.	Wheel diameter, mm.	Total weight empty, in metric tons.	Axle load, (loaded) in kgr.	Type of bogie.
		← Metres →						
Belgian National Ry. Co. .	III, I, II	22.300	2.500	14.400	1.010	III 43.— I/II 47.7	10 750 11 925	Penn., monoblock or cast steel parts. Inter., steel pressings, steel castings.
Egyptian State	I	21.061	2.438	13.716	1.143	47.5	...	Penn., steel pressings.
French State	$C^{10}yfi$	22.965	2.500	15.045	920	44 —	12 400	Penn., steel castings.
Alsace-Lorraine	B^8yfi	21.460	2 500	14.570	920	42.—	11 700	Penn., steel castings.
French Est	wood	19.370	2.500	12.630	1.050	...	S 10 000	Inter., steel pressings.
	all-metal	23.530	2.500	15.500	920	...	S 13 000	Penn., steel castings.
French Midi	B^9yfi	22.560	2 500	14.680	920	46.1	12 772	Penn., steel castings.
French Nord	A^8yfi	22.350	2.500	15.500	920	48.—	...	Penn., monoblock, steel castings.
	B^9yfi	22.352	2.500	15.502	920	48.—	...	
	$C^{11}yi$	20.850	2 500	14.000	920	43.5	..	
	Dd^4yi	20.254	2.500	13.404	920	39.—	...	
Paris-Orleans	A^8yfi	23·432	2.438	15.000	920	...	11 486	Penn.
Paris-Lyons-Mediterranean .	A^6C^6yfi	21.580	3.000	14.450	1.050	50.1	13 145	Penn., monoblock, steel castings.
	A^8yfi	23.370	2.500	15.490	920	46.8	12 545	
	B^9yfi	22.560	2.500	14.680	920	46.4	12 855	
	$C^{11}yfi$	22.085	2.500	15.085	920	43 3	12 365	
	Dd^2yi	20.020	2 500	13.480	1.050	34.7	11 670	Inter., steel pressings.
Italian State.	I, II, III, I/II	21.040	2 500	14.520	1.010	I 40.4 II,III 40.3 I/II 40.8	10 800 10 650	Inter., steel pressings.
Polish State	...	22.020	2.125	14.600	1.000	44 – 46	...	Penn., steel pressings.
Rumanian State	Aal	21.040	2.500	14.520	1.000	42.4	...	Inter., steel pressings.
	Cal	19.750	2.500	13.500	1.000	38.—	...	Inter., steel pressings.
Czechoslovakian State . .	Ca	22.750	2.500	13.500	1.000	44.4	12 800	Penn., steel pressings.
Jugoslav State	I/I .	19 650	2.150	13 000	...	...	...	Görlitz.

Note: Penn. = Pennsylvania.
Inter. = International.
l = leaves.

riages.

TABLE 6.

Play on each side (in mm.) of axle guard in the box. transv.	Play on each side (in mm.) of axle guard in the box. long.	Side movement of bogie bolster, in mm.	Spring gear: between wheels and bogie frame.	Spring gear: between bogie frame and body. (Ell. lasm. springs).	Angle of rotation of the bogies.
2	1.5	± 20	Helic. springs ∅ 37, 25/—.	6*l* 90×10/15.98.	...
		± 20	< 4 indep. spr., 9 *l.* (3) 110×13/14. Helic. ∅ 33×17/14.	8*l* 90×9/51—.	
...	...	...	Helic. springs ∅ 34.9, 23.8, 15.9/8.5.	7*l* 88.9×11.1/11.1.	...
2	2	± 15	Helic. ∅ 37, 25/11.8.	6*l* 90×10/15.98 corridor. 12.— compart.	min. 5°
2	2	± 15	Helic. ∅ 34, 22.5, 15/16.	6*l* 90×10/16.	...
3	...	± 25	< 4 indep., 9 *l.* 90×13/15.7. ellipt. 31×21.5/12.	7*l* 90×9/54.6.	6°
3	...	± 15	Helic. ∅ 37,25/18.6, 37.6.	6*l* 90×10/32.—	7°
2	2	± 15	Helic.	...	...
2	2	± 15	Helic. ∅ 34, 22.5, 15/19.4.	6*l* 90×10/24.	5° 57′
...	..	...	Helic ∅ 31.7, 22.2, 15.9/13.	6*l* 75×10/19.	...
2	2	± 15	Helic. ∅ 36.5, 24, 16/12.	< 9*l* 100×9/24 compart. 8*l* 100×9/26.8 corridor.	6° 9′
2	2	± 15		6*l* 90×10 < 31.96 corridor. 24 compart.	6° 42′
2	2	± 15		32 corridor. 32 compart.	6° 25′
2	2	± 15		6*l* 90×10/32.	6° 33′
2	3	± 15	< 4 indep. 7*l* 90×17/8.5. Helic. ∅ 22.5/16.5.	7*l* 90×11/15.2	6° 20′
2 1/2	2	± 20	< 4 indep. 10*l* 100×13/17. 8 disc springs $\frac{180-95}{7.5}$/0.6.	7*l* 75×10/29.	5° horiz. 3° 30 vertic.
1	...	± 25	Helic. ∅ 34, 24, 16/15.	7*l* 75×10/36.	4° 11′ 12″
...	...	± 15	< 4 indep., 11 *l.* 90×13/26.8. Helic. ∅ 30 8.	9*l* 76×9/16.2.	2° 5′
...	...	± 25	< 4 indep. 10 *l.* 92×13/16.5. Helic. 18.7×36/22.	9*l* 90×9/49.5.	2° 15′
1 1/2	1 1/2	± 25	Helic. ∅ 34, 23, 16/10.2.	9*l* 90×10/11.3	7°
...	...	...	...	...	...



The leading end of all the engines is to the left hand.

EXPLANATION :

Carrying pair of wheels

Driving or coupled wheels

Longitunal / Transverse } equalising levers

Actual or theoretical point of suppor.

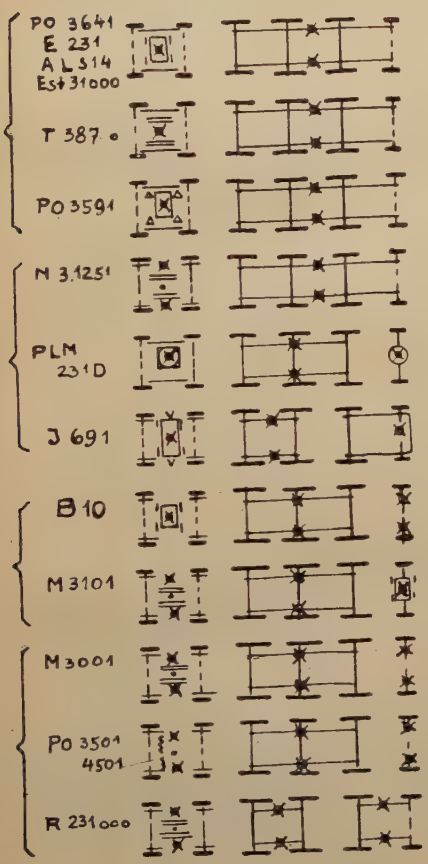
The bogie truck on the Italian locomotives I 640, 685, 746, is itself carried on three points.

Note : For explanation of abbreviations o

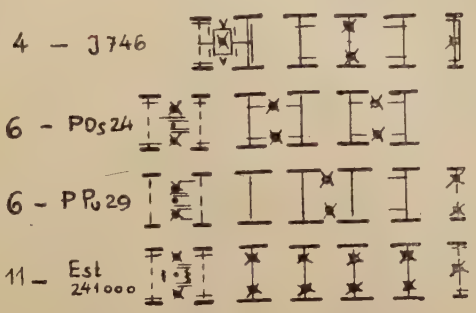
2 B = 4 - 6 - 0
2 B1 = 4 - 6 - 2
1 C = 2 - 6 - 0
1 C1 = 2 - 6 - 2

; gear. TABLE 7.

2 C 1



1 D 1, 2 D, 2 D 1

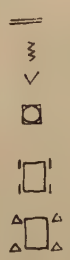


Bogie spring gear.

4 laminated springs (1 for each wheel),

2 longitudinal laminated springs.

Centering gear :



by laminated springs.

by helical springs.

by volute springs.

by inclined planes and helicoidal surfaces.

by bogie bolsters with swing links { ordinary. / triangular.

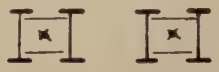
s of Railways, see table 4.

2 C = 4 - 6 - 0
2 C 1 = 4 - 6 - 2
1 D 1 = 2 - 8 - 2
2 D = 4 - 8 - 0
2 D 1 = 4 - 8 - 2

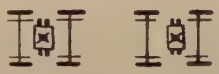
I. — Two four-wheeled motor bogies.

French Midi 4601

Paris-Orleans EBB 1-80

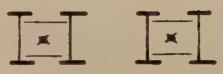


EBB 101-180



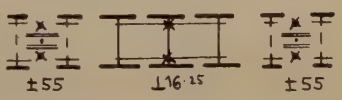
EBB 225-240

French State locomotor

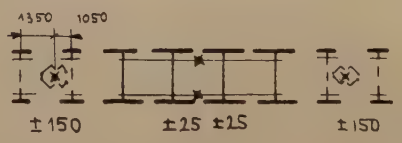


II. — Driving wheels in main frame and carrying bogies.

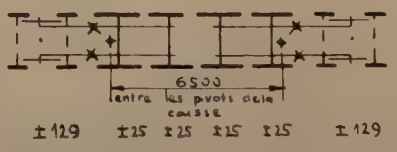
French Midi 3101



Paris-Orleans 501 502

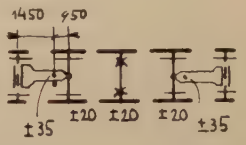


Paris-Orleans 401 402



Italian State

E 330

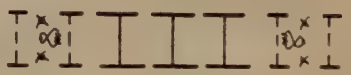


E 332

E 431

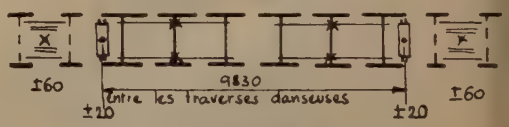
E 432

E 326

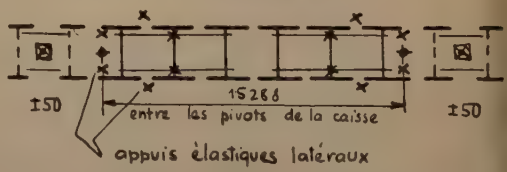


III. — Two motor trucks.

Paris-Orleans E 601



P.-L.-M. 262 AE



ension gear.

TABLE 8.

Type of comotive.	Springs: of bogie wheels. Number and cross section of leaves, in mm., flexibility in mm. per metric ton.	Springs: of driving wheels. Number and cross section of leaves, in mm., flexibility in mm. per metric ton.	How carried on the bogie.	Centering gear.	Centering force, in kgr.: initial.	Centering force, in kgr.: final.	Remarks.
4601	4 independent springs, 14 *l.*, 120×12/6.75 Helical, Ø 32/6.4.	...	Central, convex.	Coupling between bogies.	...	...	Side equalisers of body, 12 *l.*, 100×10/9.5
Orleans EBB 1	2 longitudinal springs, 31 *l.*, 130×10/8.9 Helical, Ø 29.17/8.32.	...	Central, plain.	...	...	...	...
EBB 101	4 independent springs, 15 *l.*, 110×10/6.5. Elliptic, 7 *l.*, 110×12/16.3.	...	Central, plain.	...	...	...	...
EBB 225	4 independent springs, 14 *l.*, 100×12/8.2. Helical, Ø 30/10.6.	...	Central, hollowed.	Spring coupling between bogies.	9 500	...	Side equalisers of body, 12 *l.*, 100×10/9.2
h State E locomot.	2 longitudinal springs, 130×12.7. Helical, Ø 32, 18/4.37.	...	Central, with ring.	...	...	...	...
h Midi 3101	4 independent springs, 18 *l.*, 90×8/8.	24 *l.*, 120×9/7.6.	Non supporting centres.	Laminated spring, 13 *l.*, 75×10/8.3.	4 000	7 400	2 spherical side bearings.
Orleans 501	4 independent springs, 12 *l.*, 100×9.5/4.56. Helical, Ø 29/7.78.	15 *l.*, 120×12/6.9.	...	See figs. *c*, *d*, table 4.	...	...	...
401	2 longitudinal springs, 23 *l.*, 90×13/4.25.	14 *l.*, 100×13/6.25.	...	See figs. *a*, *b*, table 4.	...	...	...
n State E 330	2 independent springs on carrying pair of wheels, 13 *l.*, 90×13/8.	15 *l.*, 120×13/5.	Non supporting centres.	Volute spring.	1 800	3 000	Zara bogie.
E 332	4 independent springs, 11 *l.*, 90×13/5.	15 *l.*, 120×13/5.	Central, plain.	Bogie bolster; volute spring.	1 800	2 800	...
E 431	2 independent springs on carrying pair of wheels, 13 *l.*, 90×13/6.	15 *l.*, 90×13/7.	Non supporting centres.	Volute spring.	1 800	2 800	Zara bogie.
E 432	2 independent springs 12 *l* 90 × 13/5 longit., 15 *l.*, 130×1[illegible]	22 *l.*, 130×10/8.	Central, plain.	Bogie bolster; volute spring.	2 000	3 000	Italian bogie.
E 326	4 independent springs, 12 *l.*, 90 × 13/5.	17 *l.*, 120×13/7.	Non supporting centres.	...	2 000	3 000	2 spherical side bearings.
Orleans E 601	2 longit., 23 *l.*, 120×11/4.6.	10 *l.*, 100×11/7.38. Helical Ø 30/8.4.	...	Laminated springs.	2 700	3 700	...
.-M. 262 AE	2 longit. 17 *l.*, 120×14/4.8.	16 *l.*, 110×12/6.75.	Central, spherical.	Inclined planes and helical surfaces.	3 130	...	...

For explanations, see tables 5 and 7.

Suspension springs on steam locomotives.

TABLE 9.

(Number of eaves, section in mm. and deflection in mm. per metric ton.)

TYPE OF LOCOMOTIVE.			Bogie with two pairs of carrying wheels				Coupled wheels.		Carrying wheels.	
			4 independent springs.		2 longitudinal springs.					
Belgian National Ry. Co.	17	4-4-0		...		...		...		...
	18	»		...		...		...		...
	20	»		...		...		...		...
	66	»		...		...		...		...
	6	4-4-2		...		...		...		...
	69	»		...		...		...		...
French Nord	2643	»	14*l*	90×10/5.2		...	16*l*	110×12/5.6	16*l*	110×12/5.6
Paris-Orleans	3001	»	14*l*	90×10/5.6		...	15*l*	120×12/6.20	15*l*	120×12/6.2
Egyptian State		»		...	16*l*	88.9×15.9/—	14*l*	88.9×14.3/—	14*l*	88.9×14.3/—
Belgian National Ry. Co.	7	4-6-0		...		...		...		...
	9	»		...		...		...		...
Alsace-Lorraine	S 101	»		...	16*l*	90×16/4.65	14*l*	90×13/9.75		...
French Est	3100	»	23*l*	100×7/9.4		...	14*l*	120×11/6.2		...
French Midi	3501	»	18*l*	90×8/8		...	17*l*	100×12/9.05		...
Paris-Orleans	1715-3201	»		...	15*l*	110×12/7.2	15*l*	120×12/6.2		...
	4001	»	14*l*	90×10/5.6		...	15*l*	120×12/6.2		...
P.-L.-M.	230 C	»		...	16*l*	120×14/7.47	20*l*	100×10/7.6		...
	230 A	»		...	10*l*	90×14/4.9	13*l*	110×12/5.28		...
Italian State	671	»	13*l*	90×13×8.—		...	13*l*	90×13/8.—		...
Polish State	OK 22	»		...	14*l*	90×16/5.7	12*l*	120×13/9.4		...
Rumanian State	230000	»		...	14*l*	90×1·/4.8	12*l*	120×13/9.2		...
Belgian National Ry. Co.	10	4-6-2		...		...		...		...
French State	231	»		...	15*l*	125×13/—		...		...
Alsace-Lorraine	S 14	»		...	15*l*	125×13/6.6	15*l*	120×12/6.7	12*l*	90×13/4.5
French Est	310000	»		...	15*l*	125×13/6.04	15*l*	120×12/6.33	12*l*	90×13/4.75
French Midi	3001-3051	»	18*l*	90×8/8.—		...	15*l*	120×12/6.64		□□28/10.—
	3101	»	18*l*	90×8/8.—		..	15*l*	120×12/6.64	14*l*	120×12/9.38
French Nord	3.1251	»	15*l*	100×10/4.6		...	12*l*	110×16/5.7	11*l*	110×12/6.3
Paris-Orleans	3501	»	14*l*	90×10/5.6		...	15*l*	120×12/6.2		□□ 28/10.—
	3591	»		...	24*l*	127×9.5/5.68	13*l*	114×11/6.2	10*l*	127×16/6.5
	3641	»		...	15*l*	125×13/4.9	15*l*	120×12/5.3	12*l*	90×13/4.—
	4501	»	14*l*	90×10/5.6		...	15*l*	120×12/6.2		□□ 28/10.—
P.-L.-M.	231 D	»		...	15*l*	120×15/4.95	16*l*	110×12/6.75		⌀ 37/12.4
Italian State	691	»	11*l*	90×13/5.—		...	15*l*	120×13/5.—	9*l*	130×15/5.—
Rumanian State	231.000	»	10*l*	90×13/3.9		...	15*l*	90×13/6.5	15*l*	90×13/6.5
Jugoslav State		»		...		...		...		...
Czechoslovakian State	3870	»		...	16*l*	90×13/17.2	15*l*	90×13/8.3	15*l*	90×13/6.5
OS	24	4-8-0	17*l*	90×10/8.5		...	12*l*	120×13/9.3		...
French Est	241000	4-8-2	22*l*	100×7/13.97		...	17*l*	120×11/8.2	23*l*	130×8/17.16
Polish State	Pu 29	»		...	14*l*	90×16/5.7	12*l*	120×13/9.2		...

Italian bogie.

			Carrying wheels.		Coupled wheels (transverse spring).					
Italian State	640	2-6-0	11*l*	90×13/5.—	13*l*	130×15/4.5	13*l*	90×13/8.—		...
	685	2-6-2	11*l*	90×13/5.—	14*l*	130×15/4.—	15*l*	90×13/7.—	14*l*	130×15/4.5—
	746	2-8-2	11*l*	90×13/5.—	14*l*	130×15/4.—	15*l*	120×13/7.—	15*l*	90×13/7.—

Part II : PERMANENT WAY.

I. — Strength of the permanent way.

QUESTIONS.

1. *Are your lines classified according to the axleload =*

$$\frac{\text{tare weight + live load}}{\text{number of axles of the vehicle,}}$$

or by the weight per metre =

$$\frac{\text{tare + live load}}{\text{length of the vehicle over buffers}} \ ?$$

2. *When classifying the lines from the point of view of the design of the permanent way, do you take into account, in addition to the maximum allowable running speed, the number of trains, the gradients and curves, and any other factors ?*

3. *Is it possible to propose and on what bases, an international classification of lines ?*

4. *How do you calculate the strength of the permanent way (formulæ with explanations) ?*

What are the maximum stresses allowed on your railway as regards the rails, sleepers and switch points ? How do you take into account the longitudinal stresses in long rails ?

Are the maximum stresses allowed dependent upon the type of track ?

Do you take the running speed into account when calculating the permanent way ?

5. *What design of permanent way do you adopt for heavy axle loads and high running speeds (weight of rails in kgr./m.) ; length of rails in metres ; rolled or welded long rails [length 25 m. (82 feet)] ; sleeper spacing in cm., along the rail and at the joint, with wood or metal sleepers ; type of rail fastenings used on wood or steel sleepers ; thickness in cm. of the layer of ballast below the top face of the sleeper on curves, measured below the inside rail ; for both wood and steel sleepers is ballast rammed or compressed by roller ?*

Please attach drawings and descriptions.

6. *In the case of lines over which trains run at high speeds have you made provision for preventing the track getting out of level, the ballast from swelling due to frost, and overcoming the unfavourable subsoil conditions by layers of sand or ashes, by drainage or other methods ?*

* * *

The question of the strength of the track is in itself too large to be condensed within the limits of the present report even in the briefest manner. The earliest endeavours to establish a method by which to calculate the strength of the track date back to nearly 100 years. The theoretical bases of the calculation were set out by Winkler in 1867 and 1875. Zimmermann developed his general calculation of the track in 1888, his method being based on the works of Winkler, Lehwald, Riese, Schwedler and others. Winkler was the first to apply the principle of the proportionality between the pressure of the rail and the elastic deflections of the supports into the ballast, which is called the ballast coefficient.

In addition attempts were made to support the theoretical investigations by results obtained by direct observation and by experimental measurements. The wellknown works by Wasiutynski, Ast, Weber, and others remain of lasting value.

The stress acting on the track cannot be calculated statically alone. It must also be considered from the dynamic point of view and becomes extraordinarily complex if vibratory phenomena in the vehicles as well as in the track

are also taken into account. In principle we start from the transmission of the forces from the vehicle to the track. In this connection a very thorough theoretical knowledge not only of the relationship between the forces acting on the track but also of the observation and measurement of the effects thereof is also necessary. The loads of the wheels transmit to the track dynamic as well as static forces. The parasitic movements of the vehicle are divided into six categories relatively to the three axes of the vehicle X, Y and Z. There are three rotational effects : about the parallel horizontal axis (oscillations called *rolling*) ; about the horizontal transverse axis (oscillations called hunting); and about the vertical axis at right angles to the track (oscillation called nosing); and three forces of translation : longitudinal, transverse and vertical. When carrying out investigations, certain hypotheses have to be made as regards the oscillations, etc. If the vehicles and the track are supposed to be in good average condition, these fundamental values should be deduced either from a consideration of the design of the vehicle, such as the flexibility and friction of the springs, the amount of the side play allowed in the axle boxes, the value of the vertical component of the centrifugal force due to the counterbalance weights, etc. ; or these values should be determined from unequalities in the level of the track in the vertical and transverse directions. As an example, following Couard's method, for well-maintained track, the variation of level may be taken as 6 mm. (15/64 inch); for badly maintained track, 12 mm. (15/32 inch); and for very bad track, 24 mm. (15/16 inch). The deflection of the rails under load at low or high speeds is evaluated very differently by different investigators. For high speeds the observations recorded have not supplied sufficiently definite bases especially on the influence of speed on the extent of the elastic deformations, nor on the influence exercised by possible track irregularities on the magnitude of the parasitic oscillations.

The exactitude of the theoretical calculations of railway permanent way is made difficult by the lack of knowledge on certain influences, such as the values of different types of vibrations and of damping out of the vibrations, which so far have hardly been enquired into.

The values of the contact stresses and the specific pressures between the wheel and the rail under the influence of which the depression and consequently the deformation of the whole is produced depend upon the quality of the steel. This also influences the rolling friction and the adhesion. There is still great lack of certainty as to the values of the transverse forces. These forces are acting either towards the centre of the curve, as for example the radial component of the tractive effort, and the transverse friction, or even alternatively in the direction of the centrifugal force itself, as the shocks of the flange against the side face of the rail head in the rotary movement of the vehicles round the vertical axis. These transverse forces influence the torsion in the rails.

Not less important is the consideration of the repetition of stresses, and above all the work-hardening of the rolling surface.

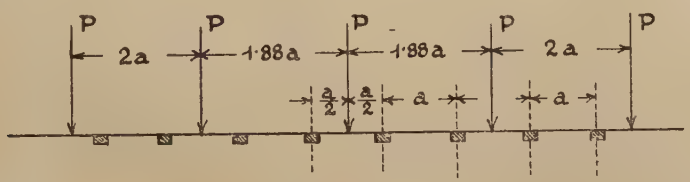
Besides the transverse forces, the longitudinal forces also are most frequently neglected in calculating the dimensions of the rail section, although their values are fairly high. For example, the interior stress in long lines of welded rails without expansion gaps for a temperature difference of 1°C, are as high as 24 kgr./cm², i. e. 190 lb. per sq. inch per 1° F. ($= \alpha$ E).

Among the vertical forces, the values of the vertical live load of the wheels caused by the oscillations of the vehicle about the longitudinal horizontal axis X are still less precisely known. This oscillation is set up in various ways, and

may for example be set up by dissymmetrical differences in level in the track. In the same way the influence of the centrifugal force and of the wind on the part of the vehicle carried on springs produces a rotary movement round the axis X, a dissymmetrical deflection of the springs, and as a consequence a live load on one rail. The consequence of these phenomena and conditions is that the cause of many broken rails remains unexplained, and that the observations differ sometimes from the results of the theoretical calculations. Both the theoretical and empirical formulæ for calculating the dimensions of the track nonetheless make at least a relative comparison possible and are in this respect essential for deciding if the maximum axle loads and the maximum speeds allowed for the different types of track or vehicles are correct.

Some of the formulæ employed have been based on the action of an isolated load or of a series of loads. The calculation on the basis of the action of an isolated load gives greater moments, but lower pressures of the rail on the sleepers. The dynamic influence is in some formulæ partly either allowed for directly, or else is taken into account indirectly in the sense that the allowed maximum stress is reduced proportionally.

For the static load on the rail, Winkler introduced the formula $M = 0.1888\ Pa$, in which P is the static weight of the wheel and a the sleeper spacing for a series of loads arranged as in the following figure :



For the dynamic load on the rail, $M = 0.1888\ Pak$, in which $k = 1 + 0.1888 \frac{Pa V^2}{EJg}$ and expresses the influence of the centrifugal force during the movement of the wheel on the rail over the reentrant curves connecting different gradients on which the centrifugal force increases the reaction of the wheel load. This gives for a stationary load a rail stress of :

$$\sigma_0 = \frac{0.1888\ Pa}{W};$$

and for a moving load :

$$\sigma = \frac{\sigma_0 J}{J - 0.00000007\ PaV^2}.$$

Applying these formulæ, the maximum allowable stresses should be more narrowly limited having regard to the fact that the whole of the dynamic forces and other factors have not been taken into account.

According to Zimmerman, for a separate load :

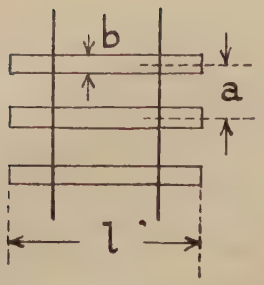
$$M = \frac{Pa}{4} \cdot \frac{8\gamma + 7}{4\gamma + 10}.$$

According to Engesser :

$$M = \frac{Pa}{4}\left(0\ 917\sqrt[4]{\gamma} + \frac{0.109}{\sqrt[4]{\gamma}}\right).$$

According to Timoshenko :

$$M = \frac{Pa}{4} \cdot 0.985\sqrt[4]{\gamma} \text{ wherein } \gamma = \frac{B}{D}.$$



$B = \frac{\sigma E J}{a^3}$, the force producing a deflection of the rail of 1 centimetre (13/32 inch).

$D = \frac{C b L}{[\eta \rho]}$, the force producing a deflection of 1 centimetre (13/32 inch) of the sleeper, in which.

$L = \sqrt[4]{\frac{4EJ}{Cb}}$, and $[\eta\rho]$ the auxiliary value according to Dr. Zimmermann's table No. VI.

C = ballast constant.

By means of these last three formulæ, the static moments are calculated and from these latter the stress of the rail on the elastic sleepers by a load at rest is obtained. When making the calculations the tables giving the values L, $[\eta\rho]$ as well as the diagrams of Dr. Zimmermann's treatise are used.

For a series of moving loads, lines of influence, and if need be Krackovsky's tables or Ritter's graphical method and tables are used to calculate the moments in play and the reactions of the rails on their supports, by considering a series of loads, either on the one side of the point examined, or by loads arranged symmetrically on both sides of this point.

The International Railway Union (U. I. C.) has carried out an investigation in order to unify the principles on which to base the calculations of the track, which however has not given positive results. Some railway administrations consider it unnecessary to determine by calculation the required dimensions of the detail parts of the track and establish them according to experience ; the others use different formulæ, and owing to the defects in those used up to the present have to be content with relative results for purposes of comparison whilst at the same time basing their practice on their own experience.

The formulæ only take into account vertical forces. The dynamic moment $M_1 = M\mu$, in which M is the static moment and μ the coefficient expressing the dynamic influences which depend directly on the speed of the trains. The tension $\sigma = \frac{M_1}{W}$. Up to the present it has not been possible to establish accurately the law of the variation of the coefficient μ with the speed of the train ; in the same way the methods of calculating dynamically the permanent way have not yet been fully explored. These dynamic influences are not harmful so long as the construction of the vehicles and of the track allows the exterior work due to the shocks to be transformed into elastic work. This can be more easily provided for in the vehicle than in the permanent way. The growing requirements of railway traffic with regard to the weights on the wheels and the running speeds force the permanent way builder to use heavier track, especially as regards the section and weights of the rails, or to lay the sleepers closer together with a thicker layer of ballast. The stronger road is at once more rigid, and less able to transform the dynamic stresses into elastic work. The dynamic forces would have to be calculated, but on the basis of the results obtained by experiment, particularly at high speeds.

With this object in view suitable dynamometric appliances for ascertaining the influence of the vertical forces and more especially of the transverse forces would have to be available.

The most important problem in the strength of the track is still that of the rail joint. So long as it is necessary to have joints their number should be reduced to the minimum. In tunnels and everywhere where differences of temperature do not cause too great longitudinal stresses the longest possible length of rail without joints should be selected. On bridges it is always desirable to avoid as far as possible rail joints and to make provision for the rails to expand freely. On running lines, it would appear that with suitably designed rail joints, for the maximum expansion of 15 to 20 mm. (19/32 in. to 25/32 in.), the maximum length of rail of 25 to 30 m. (82 ft. to 98 ft. 5 in.) is quite suitable.

Measurements and observations of the dynamic forces acting at high speeds ought to be made, particularly at the joints. It is important to find out if the stresses in these joints, starting from a certain speed, continue to increase under the dynamic forces and in what measure.

The investigation of the transverse forces which, other than the horizontal centrifugal force, are not up to the present known and determined with sufficient accuracy, opens a wide field of theoretical and experimental research. The deflection of the rails should be measured as it enables the values of the transverse forces to be determined under normal traffic conditions on the lines, as in Weber's tests, the American tests, and the others.

In the same way, so that the ratio of the forces the vehicle sets up on the track may be accurately known, it is important to ascertain if the forces act at the same time, i. e. to note phenomena which occur simultaneously and prevent others from being produced. This concerns the vertical, transverse, and longitudinal forces.

In the case of the vertical forces, the values of which are relatively well-known, there still exists some incertitude as regards the values of the ballast constant which Winkler designated by the sign C.

The experimental trials should not stop at measuring the vibrations of the vehicles and the values of the maximum transverse oscillations, etc. Obviously as a preliminary, use will be made of the experimental tests already carried out, and especially the American tests. As the « Progress Report » for 1918-1922 shows, if main line permanent way tests are to be carried out systematically, a considerable expenditure and an immense amount of preparatory work which could hardly be required of the different railway companies, are necessary. As too the results would most probably be used by all the railway administrations in certain interested districts, such tests, measurements and observations should be made with the cooperation and especially with the financial participation of the most important railway administrations. A project of this kind has already been laid before the International Railway Union.

Questions 1 to 3. — The replies sent by the railway administrations show that an endeavour is being made to classify the different lines, according to the axle loads (vehicles in transit, U. I. C.), the importance of the traffic on the line, and especially the speed of the trains. When drawing up the questions we had in mind only railways on which the axle loads are heavy and the running speed high.

Some railway administrations design the track and especially the rails according to a formula; others on the practical experience on their own particular railway (*see table I*). When calculations are made the vertical static forces are only taken into account. The dynamic effect is taken into account to a restricted extent only.

Questions 4 and 5. — The French

main line Companies, other than the Alsace-Lorraine Railways, do not base the permanent way design on calculations : they have arrived at the type of permanent way in use at the present time as the result of experience. For example, the Paris-Lyons-Mediterranean Railway considers that locomotives with axle loads of approximately 20 tons can be allowed to run at high speed over a track with 46-kgr. (92.7 lb. per yard rails, with sleepers spaced at 0.54 m. (1 ft.

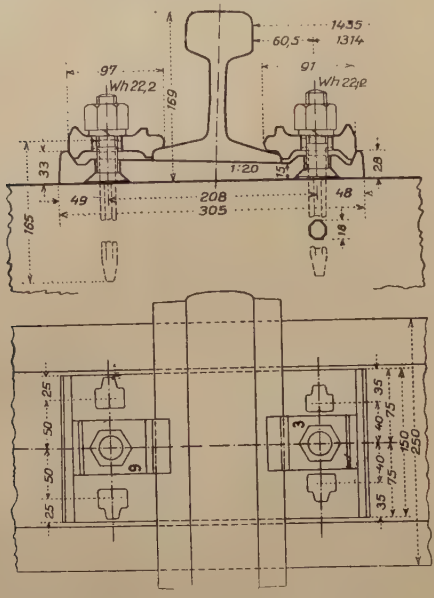


Fig. I/1.

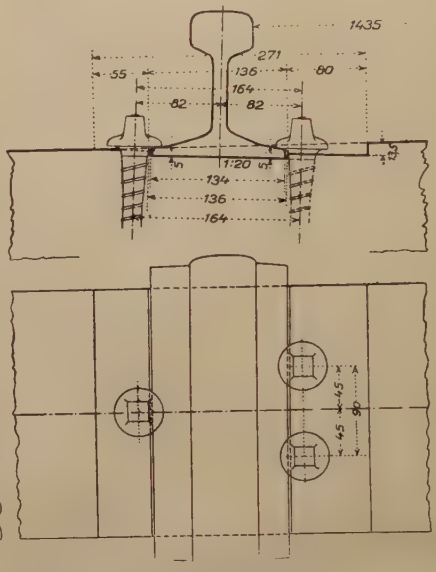


Fig. I/2.

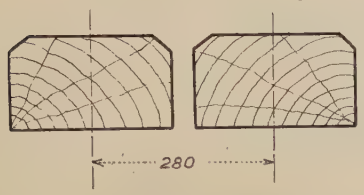
9 5/6 in.); but when the load is over 22 tons per axle a heavier rail must be used, as the sleeper spacing cannot be reduced any further.

Question 6. — As regards the equipment of the running track the replies received show there are two main types, that in which the flat bottomed rail with large foot is fastened directly to the wood sleepers by coach screws with sole plates, and that without sole plates. In the type with sole plates preference is given to the sole plate fixed by means of special fastenings to the sleeper, the rails being fixed to the sole plate by their own special fastenings. Examples of these two types are shown in figure I/1 (Czechoslovakian State Railways) and figure I/2 (standard French pattern).

As regards the *joint,* the suspended joint with the rail sleepers brought nearer together is the most usual. Certain typical arrangements are shown in figure I/3.

As regards the *cross section* of the rails, the tendency is towards heavier types of greater strength in both the horizontal and the vertical planes. The rails now weigh as much as 46 kgr. (92.7 lb. per yard), with sleepers placed more closely together, and 50 kgr. (100.8 lb.), with the sleepers rather wider apart ; the rails in tunnels are even as heavy as 55 kgr. (110.9 lb. per yard. Steps are being taken to introduce standard types of rails, for gra-

a) **French Main Line Railways, etc.**



b) **Czechoslovakian, Bulgarian, etc., State Railways.**

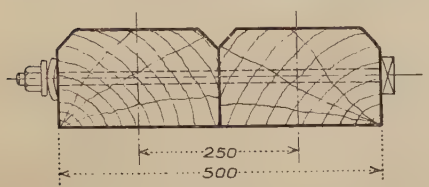
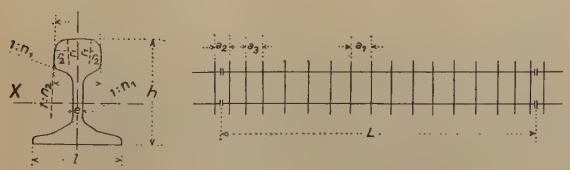


Fig. I/3.

dually replacing the old types. As regards the cross section of the rail the rounded form of the running surface predominates with a radius $r_1 = 200$ — 300 mm. (7 7/8 in. to 11 13/16 in.) and $r_2 = 13$ — 14 mm. (33/64 in. to 35/64 in.). The slope of the fishing surfaces at the joints varies between the limits of 1 in 4 to 1 in 3. The width of the foot lies between 125 mm. and 135 mm. (4 29/32 in. and 5 5/16 in.). The thickness of the web of the rail is 14 to 16 mm. (35/64 in. to 5/8 in.), and 19 mm. (3/4 in.) for tunnel rails.

Wood sleepers are mostly used, and their thickness is 14 to 16 cm. (5 1/2 in. to 6 5/16 in.).



The layer of ballast is either of the standard type of broken ballast or is formed of an upper layer — the bed properly speaking — of broken ballast of the same thickness and a lower layer of gravel, river sand, or ashes of varying thickness, according to the condition of the formation (Cf. fig. I/4 *a-c*).

In order to avoid irregularities in the level of the rails, ballast of broken stone instead of gravel is used, while unstable formations are corrected by an underlayer of sand or clinker 30 cm. (1 foot) thick, or at least by draining and by improving the side ditches so that water can freely run away, etc.

II. — Gauge widening on curves.

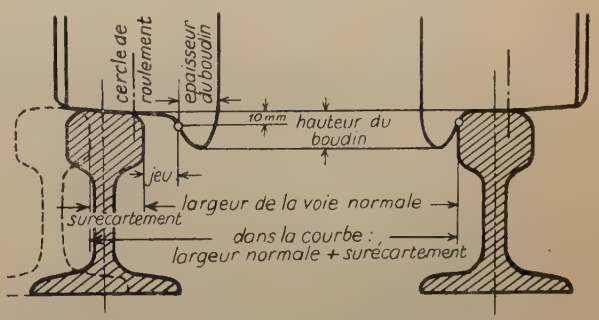
QUESTIONS.

1. *What is the width in millimetres (mm.) of the standard gauge on the straight? At what distance in mm. below the running surface is it measured?*

What variations in ± mm. in the width of the standard track on the straight are allowed?

What is the minimum and maximum play in mm. between a pair of wheels and the track on the straight?

What is the thickness in mm. of the flange measured 10 mm. (13/32 in.) below the maximum and minimum tread diameter? (see figure below).

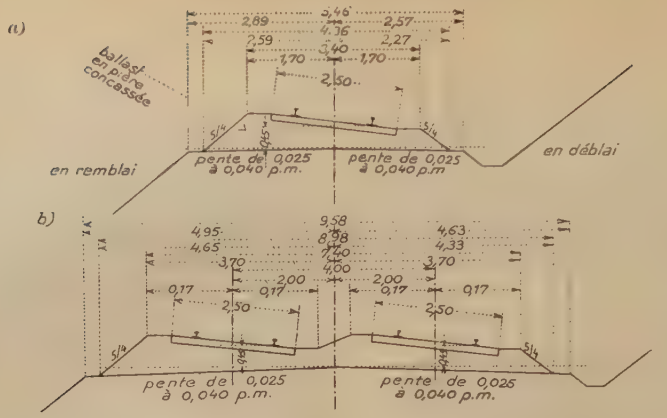


Explanation of French terms:

Cercle de roulement = Tread circle. — Epaisseur du boudin = Thickness of flange. — Hauteur du boudin = Depth of flange. — Surécartement = Gauge widening. — Largeur de la voie normale = Standard track gauge. — Dans la courbe = On the curve. — Largeur normale + surécartement = Standard gauge + widening.

What is the depth of the flange measured from below the tread circle.

Czechoslovakian State Railways.



Paris-Lyons-Mediterranean Railway.

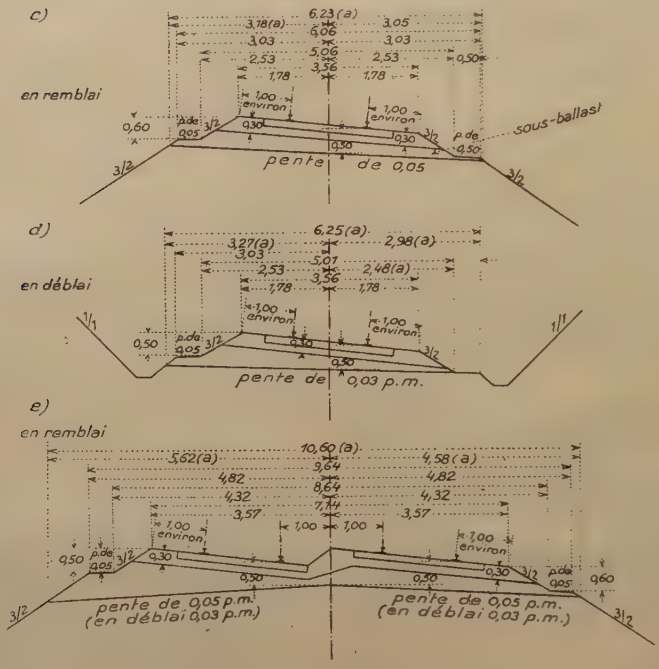


Fig. I/4.

Explanation of French terms:

Ballast en pierres concassées = Broken stone ballast. — En remblai = Embankment. — En déblai = Cutting. — Pente de... à... p. m. = Slope of... cm. to... cm. per metre. — Sous-ballast = Bottom ballast.

Note I. — The height above datum of the longitudinal section of the formation is given by that of the formation on the centre line of the two tracks.

The height above datum of the longitudinal section of the track is given by the lower rails.

Note II. — In the case of formations not solidified and imperfectly drained, and formations on rock with projections the total minimum thickness of ballast is increased according to the type of the formation up to 0.80 m. (2 ft. 7 1/2 in.), this height having to be provided always on formations on clayey ground. The additionnal thickness is made up with bottom ballast. The heights (*a*) will consequently be increased.

When the top edge of the side slope of the ballast is more than 0.50 m. (1 ft. 7 11/16 in.) above the formation, in line with this edge, a cess 0.50 m. wide is provided 0.50 m. below it formed of bottom ballast cut into the side slope of 3/2.

Note III. — Over masonry arches, reinforced concrete slabs or arches, and slabs surrounding metal girders, the total thickness of ballast and bottom ballast should be as far as possible 0.70 m. (2 fr. 3 1/2 in.), this thickness being taken above the weathering course over the arch; in no case may it be less than:

0.70 m. (2 ft. 3 1/2 in.) above masonry arches;
0.60 m. (1 ft. 11 5/8 in.) above reinforced concrete floors or arches;
0.50 m. (1 ft. 7 11/16 in.) above the slabs surrounding metal bridges.

2. *Is the increase in gauge calculated theoretically (if so according to what formula?) or is it the result of practical experience?*

Please attach a table indicating the amount the gauge is widened for the different curve radii R.

3. *What variations in ± mm. of the widened gauge on curves are allowed?*

4. *Does the gauge widening on the transition curve between the straight and the curve increase gradually (graduation in mm.) or uniformly?*

5. *How much is the gauge widened on the curve of the turnout, on the straight to the point of the tongue and to the heel; what amount is the gauge widened in the case of a turnout with the crossing on a curve, on the curve to the nose of the crossing?*

Please give separately the amount the gauge is widened in each case for the various designs of switches with different radii of curve.

* * *

Questions 1 to 5. — Tables II/1 and II/2 give detailed particulars in respect to the normal gauge of the track on the straight, the tolerances allowed, the play between the wheel and the track, the thickness and depth of the flange as well as the gauge widening on curves.

As regards the switches especially, the gauge is not widened on the straight except, however, at the point of the blade whereat, in certain designs, the stock rail of the branch is slightly cranked to take the point of the straight tongue. The resulting widening of the gauge is most frequently 10 to 15 mm. (25/64 in. to 19/32 in.). The return to the standard gauge is progressive over a short length before the point and after it. In the curve between the turnout and the crossing of the branch line the gauge is generally widened. Some Administrations use in this part of the junction the same wider gauge as on the open road; the others reduce it. For example when the turnout includes a radius of curvature between the heel of the turnout and the rail of the crossing of less than 300 m. (15 chains) the Paris-Lyons-Mediterranean Railway Company use in this part a uniform gauge of 1.450 m. (4 ft. 9 in.). Some French Administrations use crossings on curves. On running onto the crossing the gauge of the branch line is the same as that of the particular curve. This widened gauge is progressively brought back to the standard gauge of the straight line at the point the crossing is left.

During the last years endeavours have been made to adopt a smaller gauge widening in order to obtain better guiding of the vehicles and reduced resistances. We have attempted to give hereafter a solution to this problem.

The object of widening the gauge on curves is to make it easier geometrically for the vehicle to run through them freely. In the space between the pair of wheels and the track we have to note the so-called « play » found even on the straight. Its object will be explained in detail further on. The determination of the desirable play is not only a question of the geometrical passage of the vehicle but also depends on the form of the tyre and of the rail head. If we realise that these forms are subject to alteration through wear, obviously in our investigation we have also to consider the forces acting between the wheels and the rails and in particular the friction. On curves, the gauge widening and the play evidently join under the sole definition of « total play ». The total play on curves should be so arranged that the curve resistances are the smallest possible.

The frictional resistances on curves can be calculated theoretically to close limits. Nonetheless, empirical formulæ are commonly used, such as for

example that of Röckl $w = \frac{5\,000}{R-30}$, although this formula only takes notice of the radius of the curve without taking into account other factors, such as the gauge widening, the play, the wheel base, the friction, etc. The value of the frictional resistance on curves can, according to Dr. Bäseler, be calculated from conditions of equilibrium relative to three axes (6 equations).

Our task is to find a suitable theoretical formula for the gauge widening on the curve to allow vehicles to pass through geometrically. In this way, we shall not solve the question of the value of the resistance although we endeavoured to reduce the resistances to the minimum.

The tyres are conical in order to facilitate running. If we consider the wheel sets with the tread at an angle of 1:20, the total elimination of longitudinal sliding frictional resistance would necessitate the transverse displacement of the wheel set from the central position in the proper running position (without sliding friction) by

$$j = \frac{a.r.20}{2R} \quad \ldots \text{(fig. II/1)}$$

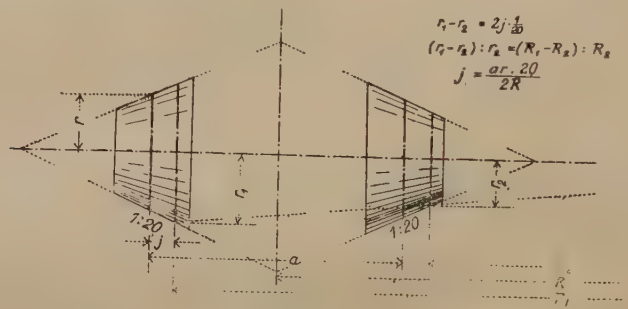


Fig. II/1.

i. e., for example when R = 300 m. (15 chains), a = 1.50 m. (5 29/32 in.), r = 0.50 m. (19 11/16 inches), J = 25 mm. (63/64 inch).

If then the conical running has to be obtained by the slope of the tyre, the play between the wheel and the rail should be considerable. In view of a limiting value of the play as well as the various radii of curves, the inclination of the tyres is not likely to reduce the longitudinal sliding friction very much. A greater difference in the radii of the tread circles is due to the radius between the flange and the tyre. But if the form of the curve connecting the flange and the tyre should help to increase the tread circle, the wheel should be pressed against the outside rail, and in this case it should come into contact with the rail at a given angle. When the axle is in a radial position, this pressure is lacking and for this reason in this case the radius of the root of the flange cannot facilitate the conical running. If we consider a 4-wheeled rigid wheelbase vehicle on a curve, the outside wheel of the leading pair meets the rail at point a (fig. II/2) at an angle

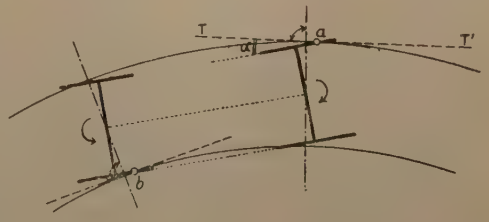


Fig. II/2.

α : the radius of its tread circle increases and the pair of wheels has a tendency to turn into a nearly radial position. If similarly the inside wheel of the trailing pair touches the inside rail at point b, this pair of wheels also turns in the opposite sense into a nearly radial position.

The result is that a double guiding of the vehicles with rigid axles (i. e. in the oblique position) is a drawback because it increases the curve resistances. Contrariwise the single guiding of the vehicle, i.e. done solely by the guiding wheel, at the point a, by making this wheel go forward and the leading axle turn towards the radial position is advantageous. In the case of vehicles with radial axles, freely suspended, i.e. free to move transversely and able after coming back to the normal position to turn to the radial position, the play in question is absolutely necessary to guide the leading pair of wheels. Against this in the case of radial axles mechanically connected with the other axles which are forced to return rapidly to the radial position, there is no need on curves for either play or gauge widening.

The value of the longitudinal friction compared with the transverse friction is not considerable, however. If for

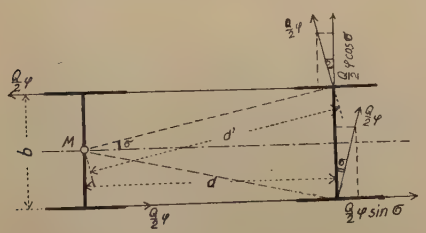


Fig. II/3.

example we imagine in the case of a 4-wheeled vehicle, that the friction centre, (i.e. the vertical axis of rotation) M falls on the centre of the trailing pair of wheels (fig. II/3) the work done in transverse friction when the vehicle is rotating through the angle η is :

$$Q\varphi \cos \sigma d\eta = Q\varphi \frac{d}{d'} d\eta = Q\varphi d\eta,$$

and the work done in longitudinal friction :

$$Q\varphi \sin \sigma \frac{b}{2} \eta + Q\varphi \frac{b}{2} \eta = Q\varphi \frac{b}{2} \eta,$$

in other terms the influence of the transverse friction is approximately $\frac{2d}{b}$ times greater.

If M lies on the centre line of the vehicle (fig. II/4) i. e. on the vertical axis

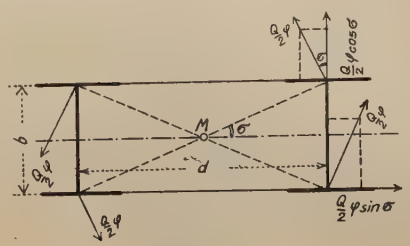


Fig. II/4.

passing through the centre of gravity, the work done in transverse friction is :

$$\frac{4Q}{2} \varphi \cos \sigma \frac{d}{2} \eta = Q\varphi d\eta$$

and the work done through longitudinal friction :

$$\frac{4Q}{2} \varphi \sin \sigma \frac{b}{2} \eta = Q\varphi \frac{b^2}{d} \eta,$$

in other terms the influence of the cross friction is $\frac{d^2}{b^2}$ times greater.

As regards short vehicles, and this is the case for most rigid wheel base vehicles, this ratio is less because it is directly proportional to the wheel base. For this reason and so far as this type of vehicle is concerned, it is not possible to avoid having a certain amount of play between the wheel flange and the rail,

as it is needed to guide the leading pair of wheels. If the play is too small it would result in the wheels more frequently taking an oblique position with the consequences mentioned above.

On curves, the gauge widening is in addition to the play between the flange and the rail ; this is why the gauge widening should not be excessive. By limiting it, the same method of laying the track can be used on the curves as on the straight. Another advantage is that owing to the reduction of the angle at which the wheel comes into contact with the rail, the transverse component of these forces is reduced, and consequently the wear of the flanges and of the rail heads ; the reduction of the amplitude of the horizontal nosing movements of the vehicles means smaller dynamic transverse forces. On the other hand, we must not loose sight of the fact that a tighter gauge on curves means that the rails must be more securely fastened to the sleepers while an elastic yielding flexion of the rails must be possible.

Some Railway Administrations have recently reduced the gauge widening on curves (for particulars, see table II/1). Certain Companies formerly using the widened gauge of 1.445 m. (4 ft. 8 7/8 in.) on the straight have changed over to the standard 1.435 m. (4 ft. 8 1/2 in.) gauge.

The need for gauge widening depends upon the construction of the vehicles, especially as regards the arrangement, number and distance between the pairs of wheels. This is why it is not possible to satisfy all conditions by a given widening of the gauge.

The problem of the widened gauge on curves to allow the vehicles to negotiate the curve, is a geometrical one in which we have to study the ratios between the radius of the curve, the wheel base, and the gauge widening. Let us examine the case of a 4-wheeled rigid vehicle with a wheel base d and a wheel diameter r on a curve of radius R, geometrically able to run freely :

1. The play between the wheel set and the track on the straight line should also be maintained on the curve ;

2. In principle, the outside wheel of the guiding axle should make contact with the outside rail at the smallest possible angle. When this angle reaches its maximum the inside wheel of the trailing axle should touch the inside rail tangentially, i.e. the trailing axle should be almost radial.

The study of the inscription of the vehicle can be based upon two fundamental positions :

a) Vehicle in a symmetrical position.

In this position the two outer axles are symmetrical relatively to the line through the centre of the curve at right angles to the longitudinal axis of the vehicle. Let us consider the 2 outer wheels as pressed against the outside rail. In this position, the angle of contact α has its minimum value. The two axles are at an angle α to the radial postion. The length of the secant of the outside rail circle is approximately $d + 2u$, in which $u = \sqrt{2rt}$ (see fig. II/5, 6, 7), and the length of the secant of the inside rail circle $d - 2u$. Let us then take a = standard gauge, s = the gauge widening, j = the play, b = the outside distance over the flanges.

Under the hypothesis of $s = 0$, we get the ratio between R and d for the case where it is not necessary to widen the line on the curve, for example when $d = 4.50$ m. (14 ft. 9 in.) R is equal to 73 m. (3.65 chains). The vehicle can be inscribed in the curve, the angle of contact of the outside wheels is at the minimum and consequently the transverse force is least. However, in this position, as will be seen from fig. II/7, the inside wheel of the trailing pair of wheels intersects the inside rail. The

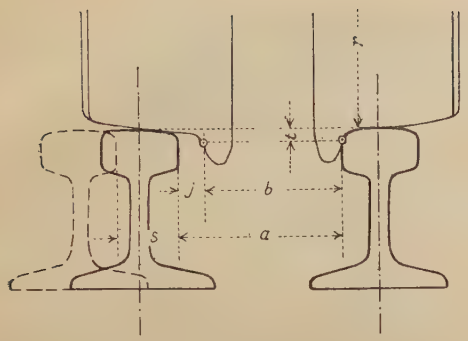


Fig. II/5

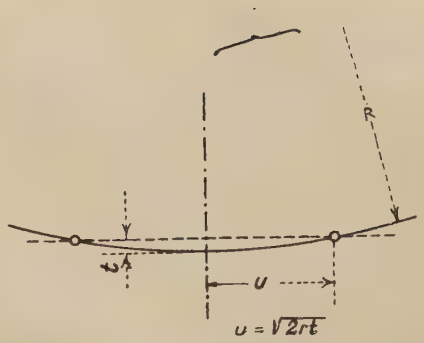
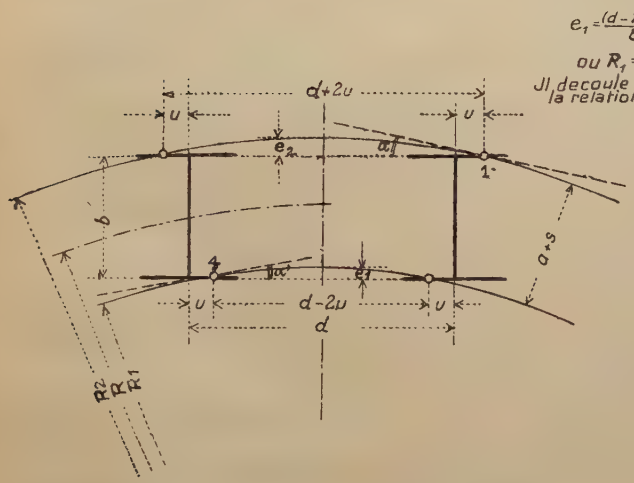


Fig. II/6.



$e_1 = \frac{(d-2\sqrt{2rt})^2}{8R_1}$, $e_2 = \frac{(d+2\sqrt{2rt})^2}{8R_2}$

ou $R_1 = R - \frac{a}{2}$, $R_2 = R + \frac{a}{2}$

Il découle de la relation $b + e_2 = a + s + e_1$

$s = e_2 - e_1 - (a-b)$

$$s = \frac{8dR\sqrt{2rt} - d^2a - 8rta}{8(R^2 - \frac{a^2}{4})} - (a-b) \qquad (I.)$$

$a - b = j$ ..... p. ex. 0·01

$r = 0{\cdot}5$, $a = 1{\cdot}435$, $t = 0{\cdot}02$, $\sqrt{2rt} = 0{\cdot}142$

$$s = \frac{1{\cdot}136\,dR - d^2a}{8(R^2 - \frac{a^2}{4})} - 0{\cdot}01$$

$$s = \frac{1{\cdot}136\,dR - 1{\cdot}435\,d^2}{8R^2 - 4{\cdot}12} - 0{\cdot}01 \qquad (II.)$$

Fig. II/7.

secant makes an angle α' with the tangent at the point 4. From this fact the radial force causing friction in the longitudinal direction is set up at this point. The vehicle passes through tightly seeing that the outside wheels are in contact with the rails and that in consequence neither the rotation nor the transverse displacement of the vehicle is possible. As a result of the insufficient play the rail must yield by an elastic deformation or the two wheels will skid. This close guiding has however the advantage that the dynamic effects of the transverse forces are (without taking into account the abnormal wear of the flanges and of the rails, nor too short vehicles with which the play is maintained) almost entirely eliminated. On the other hand the tightness of the guiding necessitates an elastic and firm rail fastening to prevent deformation, i.e. the formation of abnormal gauge widening due to the long vehicles.

In addition as there is no longer any free play the coned tread cannot be made use of.

If there is some play between the

wheel set and the track, the outside wheel of the leading set will assist, as we have mentioned above, in guiding the vehicle, by working on a greater rolling circle radius to make up for passing the inside wheel, and thereby compensate the longitudinal sliding friction having its origin in the slipping resulting from the inside wheel being passed. Consequently the play j — see condition under 1 — is necessary on curves, the same as on straight lines. We meet this condition by increasing the widening according to formula II of the value j, i.e. of the value of the play on the straight.

$$s = \frac{1\,136d\,\mathrm{R} - d^2a}{8\left(\mathrm{R}^2 - \frac{a^2}{4}\right)} \quad . \quad . \quad \text{(III)}$$

For $d = 4.50$ m. (14 ft. 9 in.) we get the following formula for the gauge widening :

$$s = \frac{5.112\,\mathrm{R} - 30.375}{8\,(\mathrm{R}^2 - 0.563)} = \frac{0.639\,\mathrm{R} - 3.79}{\mathrm{R}^2} \quad \text{(IV)}$$

According to this formula we get the following values of the gauge widenings:

R = 300 m. (15 chains).
150 m. (7 1/2 chains).
72.73 m. (3.63 chains).

s = 0.002 m. (5/64 in.).
0.004 m. (5/32 in.).
0.010 m. (25/64 in.).

respectively.

b) *The vehicle in an oblique position.*

Let us consider the extreme position of the vehicle which also satisfies the conditions under 2) i. e. when in the extreme position of maximum deviation from the tangent TT' the trailing wheel touches the inside rail tangentially. Thus as is seen from figure II/8 there is between the outside wheel of the trailing wheel set and the outside rail, a total play of $s + j = (d + 2u) \tan \delta$.

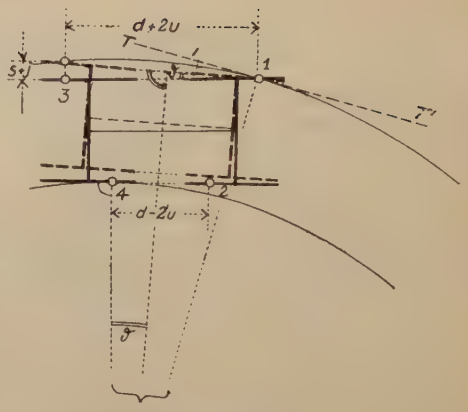


Fig. II/8.

According to figure II/8 :

$$\sin \delta = \frac{j + s}{d + 2\sqrt{2rt}} = \frac{d - 2\sqrt{2rt}}{2\mathrm{R} - (a+s)}$$

$$(j + s)\,[2\mathrm{R} - a - s] = d^2 - 8rt.$$

Let us select for j an average value between the tyre and the new and the worn rail :

for $j = 0.017$,

$$r = 0.505,\ t = \frac{0.015 + 0.026}{2} = 0.02$$

$$\sqrt{2rt} = 0.142, \qquad a = 1.435$$

$$2\mathrm{R}j + 2\mathrm{R}s - aj - as - js - s^2 =$$
$$d^2 - 8rt - s^2 + s.\,(-j - a + 2\mathrm{R}) + 2\mathrm{R}j$$
$$- d^2 - aj + 8rt = 0$$
$$- s^2 + s\,(2\mathrm{R} - 1.452) + \mathrm{R}.\,0.034 - d^2$$
$$+ 0.055 = 0 \quad . \quad . \quad . \quad . \quad \text{(V)}$$

For $s = 0$ we get the ratio between R and d :

$$\mathrm{R}.\,0.034 - d^2 + 0.055 = 0 \quad . \quad \text{(VI)}$$

$$\mathrm{R} = \frac{1}{0.034}\,d^2$$

This formula shows that it is not necessary to widen the gauge for curves of a radius greater than :

R =	596 m. (29.98 chains)	for d =	4.50 m. (14 ft. 9 in.).
	519 m. (25.95 chains)		4.20 m. (13 ft. 9 3/8 in.).
	474 m. (23.70 chains)		4.00 m. (13 ft. 1 1/2 in.).
	447 m. (22.35 chains)		3.90 m. (12 ft. 9 9/16 in.).

From equation (V) we get for d = 4.50 metres, the relation between R and s :

$$s^2 - s(2R - 1.452) - 0.034R + 20.20 = \theta \quad \text{(VII)}$$

and for d = 4 metres, the relation :

$$s^2 - s(2R - 1.452) - 0.034R + 15.95 = \theta \quad \text{(VIII)}$$

The results for s are given in the following table and diagram :

Gauge widening in mm. (*inches*).

For the radius in metres (*in chains*) R	For wheel base d =	
	4 m. (13 ft. 1 1/2 in.)	4.50 m. (14 ft. 9 in.)
180 (9)	28 (1 7/64)	...
200 (10)	23 (29/32)	34 (1 11/32)
300 (15)	10 (25/64)	17 (43/64)
400 (20)	3 (1/8)	8 (5/16)
(474) (23.37)	(0)	...
500 (25)	...	3 (1/8)
(596) (29.98)	...	(0)

As the curves of the diagram show the value of s increases rapidly in the case of small radii and exceeds the maximum allowable limit when R < 180 (9 chains) and d = 4.00 m. (13 ft. 1 1/2 in.). In the case of curves of R < 180, the maximum gauge widening of 30 mm. (1/8 inch) is recommended.

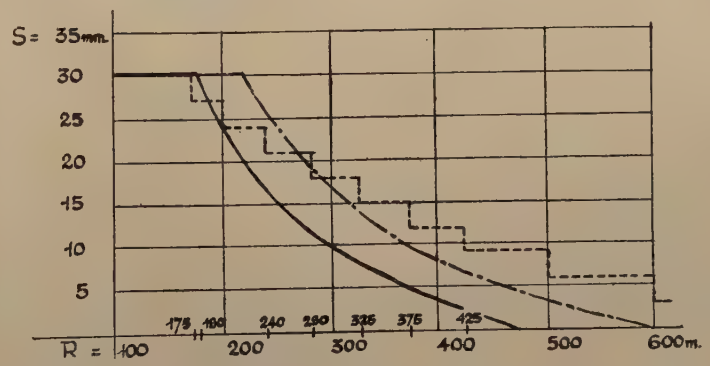
For practical use the scale for d = 4.00 m. (13 ft. 1 1/2 in.) is recommended and consequently the formula obtained from equation (VIII).

$$s = R - 0.726 - \sqrt{R^2 - 1.418\,R - 15.423} \quad \text{(IX)}$$

If we replace in equation (V) :

$$-s^2 + s(2R - 1.452) + R.\,0.034 - d^2 + 0.055 = \theta$$

s by the corresponding numerical value, we get the ratio between the radius of the curve and the maximum allowable gauge widening for the rigid axles of the vehicle which can pass through the curve of radius R under conditions 1 and 2 above. It is desirable to simplify first



Gauge widening for d = 4.00 m. } according to formulae (VII) and (VIII).
» » d = 4.50 m. }
» prescribed on the Czechoslovakian State Railways.

of all equation (V) by eliminating the less important terms, as follows :

$$s.2\ R + R.\ 0.034 = d^2$$

$$d = \sqrt{R\ (2\ s + 0\ 034)} \quad .. \qquad (X)$$

III. — Radius of curves.

QUESTIONS.

1. *What is the maximum speed allowed over curves of the different radii ?*
Please attach a table.

2. *What is the maximum speed allowed on the different gradients ?*
Please attach a table.

3. *Are the maximum allowable speeds on the curves or on gradients based on theoretical considerations (according to what formulæ ?) or on practical experience ?*

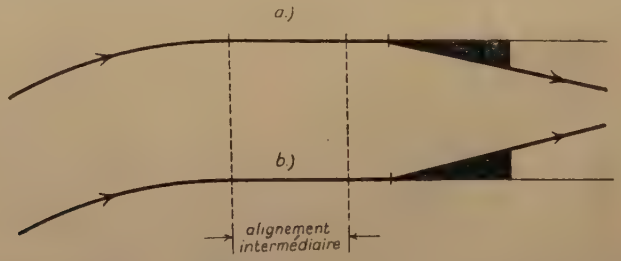
4. *What minimum radii of curves are allowed on lines over which trains run at high speeds,*
on open line,
on the curve of the turnout ?

5. *Do you insert an intermediate length of straight line between two curves in opposite directions between the initial points of the transition curves ?*
What should be the length of this intermediate piece of straight line ?
Is the length of the intermediate straight line determined according to the maximum speed ?
Do you also consider it necessary to insert an intermediate straight length on lines over which trains run at high speeds, where there are large radius transition curves and superelevation gradients ?

6. *What should be the minimum length of the straight section between curves in the same direction ?*

7. *What radii of curves are used when on double track lines one of the lines has to be laid at a greater distance between centres in the station than that of the open line ?*

8. *Do you lay a straight section between a curve and a turnout ?*
When the curve of the turnout can be run through at the maximum speed, what length should the intermediate straight section have, when :
a) *The curve of the track and the curve of the turnout are arranged in the same direction* [*sketch* (a) *of diagram*];



Note : Alignement intermédiaire = Intermediate length of straight line.

b) *The curve of the track and the curve of the turnout are arranged in reverse directions* [*sketch* (b) *of diagram*].
What should be the length of the intermediate straight section when the switch is run through trailing (i. e. with the crossing facing towards the point of the blade)?

9. *Do you insert a straight interme-*

Table III/2.

ADMINISTRATIONS.	Maximum speeds, km./h. — Gradient. ‰
BELGIUM.	
Belgian National Railway Company.	The percentage of the inclination is not taken into account.
EGYPT.	
State Railways	The gradients being easy, no speed reduction is required.
FRANCE and COLONIES.	
State Railways	The percentage of the inclination is not taken into account.
Alsace-Lorraine Railways .	) | 105 | 100 | 95 | 90 | 85 | 80 | 75 | 70 | 65 | 60 | 55 |
Est Railway	The percentage of the inclination is not taken into account.
Midi Railway	120 | 90 | 80 | 50
	According to the formula: $V \div 2i = 120$ to 140.
Nord Railway	The authorized maximum of 120 km./h. is applicable, whatever the inclination of the lines may be.
Paris-Orleans Railway . .	The percentage of the inclination is not taken into account.
Paris-Lyons-Mediterranean Railway (*).	65 | 55
State Railways in Algeria.	| Reduced to 60 km.
Moroccan Railways . . .	The percentage of the inclination is not taken into account.
ITALY.	
State Railways	| 75 | 65 | 55
LUXEMBURG.	
Prince Henri Railway . .	The percentage of the inclination is not taken into account.
POLAND.	
State Railways	100 | 95 | 93 | 90 | 87 | 85 | 83 | 80 | 77 | 75 | 73 | 70 | 67 | 65 | 62 | 60 | 58 | 57 | 55
RUMANIA.	
State Railways	95 | 85 | 75 | 70 | 65 | 60 | 50
CZECHOSLOVAKIA.	
State Railways	110 | 105 | 100 | 95 | 90 | 85 | 80 | 75 | 70 | 65 | 60 | 50 | 45 | 40
JUGOSLAVIA.	
State Railways	90 | 85 | 80 | 75 | 70 | 65 | 60 | 55

(*) For passenger trains and parcels trains fitted with the continuous brake.

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9199

Table III/3.

ADMINISTRATIONS.	Question 4.	Questions 5-6.		Question 7.	Question 8.		Question 9.	Question 10.	
	Minimum radius of curves on lines run over at high speed.	Minimum length of intermediate straight section between curves (between origins of transition curves).		Minimum radius of curves to be used on double-track lines when running onto a section where the centre lines of the two tracks are to be further apart (in stations) than with the standard six-foot way (on the open line).	Minimum length of intermediate straight section between a curved section and a junction, when the curve of the line and that of the turnout are:		Minimum length of intermediate straight section between the end of the turnout and a curve following the turnout.	For maintaining the regularity of the curves use is made of	
		reverse curves.	curves in the same direction.		in the same direction (sketch *a* of diagram, p. 2198).	in opposite direction (sketch *b* of diagram, p. 2198).		the method of measuring the heights of the arcs (versines).	fixed locating posts.
					1. Facing points. 2. Trailing points.				
BELGIUM.									
Belgian National Railway Company.	—	It is preferable not to have any straight section between transition curves.	Not laid down.	3 000 m.	—	—	—	—	/
EGYPT.									
State Railways . . .	500 m.	30 m.	Not laid down.	3 000 m.	—	—	—	—	/
FRANCE and COLONIES.									
State Railways	600 m.	Generally 100 m., 20 m. minimum.	Not obligatory.	1 000 m.	20 m.	20 m.	20 m.	/	/
Alsace-Lorraine Railways .	300 m.	30 m. 50 m. for lines run over by express trains.	No rules.	3 000 m.	—	—	6 m.	/	/
Est Railway	800 m.	20 m.	—	2 500 m.	—	—	—	/	/
Midi Railway	For V = 120 km./h., R = 1 200 m. For V = 105 km./h., R = 900 m. For V = 90 km./h., R = 700 m. (the maximum superelevation on transition curves is 75 mm.).	11 m. (or even nil when specially authorised).	Not obligatory.	6 000 m.	—	—	—	/	/
Nord Railway	500 m.: an endeavour is made to get a radius of at least 1 000 m.	15 m.	15 m.	As large as possible.	The curvature of the track, where points and crossings are run over, is made as constant as possible and the points and crossings are, therefore, laid on a curve, if necessary.		—	—	/
Paris-Orleans Railway . .	700 m.	20 m.	Not obligatory.	In principle, an endeavour is made to remain within the limits of the smallest radius corresponding to the speed on the line.	—	—	—	/	/
Paris-Lyons-Mediterranean Railway.	750 m.	20 m. The straight section is to be avoided if it cannot be 20 m. long at least.	No precise rules.	2 000 to 3 000 m.	—	—	—	/	/
State Railways in Algeria.	—	20 m.	20 m.	—	No precise rules.		No precise rules.	—	/
Moroccan Railways . . .	350 m.	20 m.	—	—	—	—	—	/	—
ITALY.									
State Railways	1 000 m. (exceptionally 800 m.)	30 m.	20 m.	2 000 m.	20 m. Θ	30 m. Θ	—	/	/
LUXEMBURG.									
Prince Henri Railway . .	500 m.	30 m.	30 m., if straight section is unavoidable.		6 m.	6 m.	—	/	—
POLAND.									
State Railways	300 m.	30 m.	It is desirable that this length be not inferior to that of the transition curve.	1 000 m.	—	—	—	/	/
RUMANIA.									
State Railways	An endeavour is made to get a radius of at least 500 m.	As far as possible, a straight section of a length equal to that of a train of average length.	100 m.	1 000 m. (min. 800 m.)	—	—	—	/	/
CZECHOSLOVAKIA.									
State Railways	Do.	For: V = 60 ÷ 70 km./h. . . 40 m. V = 70 excl. ÷ 80 incl. . 50 m. V = 80 excl. ÷ 90 incl. . 60 m. V > 90 . . . . . 100 m.	Not laid down.	R ⩾ 4 000 m. suitable for reverse curves.	For V = 70 ÷ 90 km./h. excl. . . . 20 m. For V = 90 ÷ 100 km./h. excl. . . . 35 m. For V = 100 km./h. . . . . 100 m. For V = 70 ÷ 80 km./h. excl. . . 7.5 m. For V = 80 ÷ 100 km./h. excl. . . 15 m. For V = 100 km./h. . . . . 50 m.		For: V = 70 ÷ 80 km./h. excl. 7.5 m. V = 80 ÷ 100 km./h. excl. 15 m. V = 100 km./h. 50 m.	/	/
JUGOSLAVIA.									
State Railways	300 m.	20 m.	—	2 000 m.	20 m.	20 m.	20 m.	/	/

diate length between the end of the turnout and a subsequent curve beyond the turnhout ?

Do you decide the length of these straight sections according to the maximum running speeds ?

10. *Do you use, to maintain the regularity of the curve, reference marks, or are curves, when defective, corrected by measuring the height of the arc or by other similar methods ?*

11. *On important lines for international express traffic have small radius curves been replaced by larger radii curves in order to increase the safety of the traffic and the speed of running ?*

* * *

Questions 1-3. — Tables III/1 and III/2 show the maximum speeds allowed on various radii of curves and different down gradients.

Some railways make no allowance for down gradients when fixing the maximum speed of trains fitted with the continuous brake.

Others measure the influence of the down gradient in terms of a certain braking distance, i. e. the maximum distance which the train running down the slope will run over from the time the brake is applied until the train is stopped. There is a known relationship between the braking distance on the gradient, the gradient and the maximum speed. If we select a given braking distance, for example on the Czechoslovakian State Railways, 700 m. (2 300 feet) is used on the main lines, there remains a relation between the gradient and the speed which gives the maximum allowable train speed over a given gradient.

Although the influence of the gradient does not come within the scope of this report, there is need however to call attention to the influence of the braking distance, especially at high running speeds. The value of 700 m. mentioned above for the braking distance on the main lines may be used as the basis for calculating the ratio between the gradient and the maximum allowable speed. Some railways use as braking distance a distance exceeding 700 m. The French Midi Company, for example, takes a distance of 800 m. (2 625 feet) for gradients up to 1 in 250, and 900 m. (2 950 feet) for gradients steeper than 1 in 250.

An important problem in connection with the radius of the curve is the calculation of the maximum speed relatively to the minimum radius, on the condition of a well proportioned superelevation of the outside rail. The question of the superelevation of the outer rail will be considered in chapter IV. We may however somewhat anticipate and go back to formula (X) for the superelevation :

$$h = \frac{4\,76\,v^2 - 2.3\,R}{v^2 + 29.7\,R}$$

in which v = the speed in metres per second, and R the radius of the curve. If we take, for example, $h = 0.15$ m. (6 inches) we obtain the ratio of the speed V max. (in km./hour) and the minimum radius R

$$V = 4.32\sqrt{R}$$

Minimum radius R in metres (in chains).	Maximum speed ($V_{max.}$) in km. (in miles) per hour
200 (10)	60 (37.3)
300 (15)	75 (46.6)
400 (20)	85 (52.8)
500 (25)	95 (59.0)
600 (30)	105 (65.2)
700 (35)	110 (68.3)
800 (40)	120 (74.6)

The railway administrations use empirical formulæ of great diversity for determining the ratio between the maximum allowable speed and the minimum curve radius. The necessity for accelerating railway traffic (because of automobile competition) makes it necessary to run as fast as possible through the curves. It is also desirable that sys-

tematic experimental tests should be carried out in this matter.

Question 4. — As a general rule, lines over which trains run at high speeds are laid with a minimum radius of curve suitable for the maximum speed permitted. At certain points of these lines the radii may exceptionally be reduced to lower values. Turnouts laid in curves have sometimes (French Est, Nord, and other railways) the through lines laid to a radius of curvature equal to that of the radius of the curve on the open line. The French Est Company has introduced a type of turnout with the angle tan 0.05 having a radius of 2 000 m. (100 chains) followed by a radius of 1 300 m. (65 chains) on the branch line. Provided the turnout and the branch line are superelevated, trains may be allowed to run at speeds of 100 to 120 km. (62.1 to 74.6 miles) per hour over the branch line. Outside this special case the speed of the trains on the branch line should be appreciably reduced. This speed varies from 30 to 90 km. (18.6 to 56 miles) per hour according to the radius of curvature of the branch line of the turnout.

The Paris-Lyons-Mediterranean Railway applies the same speeds over the curves of the turnouts on the main line. In the case of points the following limitations are imposed : the maximum speeds are calculated as a function of the superelevations. Below are given the maxima cants at the points :

a) Facing points, train in normal working : 6 cm. (2 3/8 inches) when the two lines of the turnout turn in the same direction, and 3 cm. (1 3/16 inches) or exceptionally 4 cm. (1 9/16 inches), when they turn in different directions;

b) Trailing points taken by the train in normal working : 8 cm. (3 1/8 inches) at the most.

As a rule the radius of the curve at the turnout either in the main direction or in the branch direction is a function of the speed. As the speed on a curve is also a function of the superelevation of the outside rail, this factor is also taken into account and if need be the turnout is put in in such a way that the outside rail in the main direction is superelevated.

Question 5. — Certain companies, such as the French Est Railway, consider that in principle there should be a straight section between two curves in opposite directions. The length of the straight section between initial points of the transition curves can be fixed arbitrarily for example at 20 m. (66 feet). On the other hand, other administrations, such as the Paris-Lyons-Mediterranean Company consider that when the curves include cubic parabola transitions, it is desirable to suppress any straight sections between the initial points of the transition curves. A straight section can in fact only encourage oscillations of the vehicles and it is necessary to avoid using it whenever it is not possible to have at least 20 m. between the beginnings of the transition curves. The Rumanian State Railways consider that an intermediate straight length is necessary between the initial points of the transition curves and endeavour to insert as often as possible a straight section, the length of which shall be equal to that of an average train. — *For particulars, see table III/3.*

No administration indicates how it calculates the minimum distance between two curves in different directions. As the above shows, the opinions relative to the amount of this length are very divergent.

The length of the train undoubtedly influences the determination of the intermediate length. An intermediate length, short or nil, is a disadvantage in the case of very long trains, owing to the resistances on the curves. If however we have in view high speeds, the con-

nection of the superelevation must be taken into account before everything. The less the inclination 1 : n of the connection with the superelevation, the smaller the speed of rotation of the vehicle round the horizontal longitudinal axis when the vehicle runs over the transition curve. For example when the speed V = 120 km. (74.6 miles) per hour the radius of the succeeding curves in opposite directions are $R^1 = R_2 = 800$ m. (40 chains), the superelevation h = 0.15 m. (6 inches) and the distance between the rails = 1.50 m. (5 feet 29/32 inches), the inclination of the exterior rail in the superelevation ramp is 0.001, the length of the connection h = 150 m. (492 feet) the angular speed will be :

$$w = \frac{h.V}{1.5\ l\ 3.6} = 0.024 \text{ or } 1^\circ 22' 31'' \text{ per second.}$$

The kinetic energy $E = 1/2\ J\ w^2$ consequently will be relatively small so that it can easily be balanced by the work done in flexion of the springs. In such a case it is better to have an inflexional connection. An intermediate straight section would exercise a disturbing influence on the continuity of the rotary movement. If the value of the inclination 1 : n of the connection with the superelevation increases the rotation of the vehicle about the longitudinal axis is more rapid and the vehicle suddenly and quickly goes into a rotary movement.

When the superelevation ramps are inclined 1 : 1 000 and in some cases 1 : 750, and when the curves have large radii the necessity of an intermediate straight section disappears even for quite high speeds.

The minimum length of the intermediate straight section is a function of the maximum train speed, of the superelevation, of the inclination of the superelevation connection, as well as of the design of the vehicles especially of the arrangement and flexibility of the springs, of the position of the centre of gravity of the vehicles, etc. The determination of this factor also affects the movement of of the vehicles. It would however be better to carry out experimental tests.

Question 6. — See table III/3. — The replies from most of the administrations show that on succeeding curves in the same direction no straight section is inserted as a general rule, but the two curves are connected together by a parabolic arc so that the superelevations may always be inversely proportional to the radius.

The Prince Henri Mining and Railway Company follows the prescriptions of the T. V. [Technische Vereinbarungen of the Verein (Association of German Railways)] and thinks it desirable to connect the two curves by a short intermediate curve of large radius. If it is not possible to introduce an intermediate curve, a straight section of a length of at least 30 m. (98 1/2 feet) can be used.

Question 7. — The Paris-Orleans Company endeavours in principle to remain within the limits of the sharpest curve corresponding to the speed over the line; the practical limits are very wide. The Czechoslovakian State Railways for example use the radius R = 4 000 m. (200 chains). This radius is used for succeeding curves in opposite directions (S form curve). The reason for using such great radii is to make good as far as possible the disadvantage of using short curves which are in this case unavoidable.

In principle the small radius curves are disadvantageous when the length of the curve properly speaking is less than the length of the transition curve, taking into account the rolling movement of the vehicles about the longitudinal axis. The larger R is, the more possible it becomes to use a lower superelevation, and the disadvantage mentioned becomes less serious. For this reason short cur-

ves should in principle be replaced by others of as large a radius as possible.

Questions 8 and 9. — There are administrations who insert straight sections between the end of the turnout and the preceding or following curve; on the other hand the French Est and the Paris-Lyons-Mediterranean Companies for example and others do not in principle see any need for a straight intermediate section between a curve and a junction except in certain special cases. Moreover there is no reason why the parabolic transition of a curve following a turnout should not begin immediately after the heel of the switch. *(See also table III/3.)*

Question 10. — Several companies maintain the regularity of the curves by using reference marks generally consisting of points in small blocks of concrete and check the curves by the method of measuring the heights of the arcs.

Question 11. — The increase of the speed of trains at the present time is becoming a decisive factor in the competition of the railways with other rapid methods of transport. In this respect the advantage is on the side of the railway company in flat country where the railways have been laid with large radii curves as compared with railways in mountainous country. All railway administrations endeavour to increase the efficiency of the railways by improving the speed on curves and by increasing the radii. Those administrations who when building their main lines had the foresight to provide for future high speed traffic are now reaping the advantage.

Thus in France, as early as 1853 a ministerial regulation limited the maximum speed to 120 km. (74.6 miles) per hour. The main French Railway Companies have in fact on their principal lines such curves as to allow the said speed to be generally adopted. As regards the ratio between the maximum speeds and the minimum radii of curve see further on, chapter IV.

IV. — Superelevation.

QUESTIONS.

1. *According to what principles do you superelevate the outer rail on curves ; what experience have you obtained and what modifications do you propose in the future in carrying out the superelevation ?*

2. *What is the superelevation* h *for the different radii of curves R and the running speeds V ?*

Please attach a table.

3. *Is the amount of the superelevation calculated theoretically or is it determined by experience ?*

What formulæ do you use ?

4. *Is the superelevation based on the maximum permissible running speed or on a lower average running speed ?*

5. *Do you use a reduced superelevation and in what cases ?*

6. *What is the variation, in* $\pm$ *mm., in the amount of the superelevation ?*

7. *Is the superelevation obtained by raising the outside line of rails alone or by both elevating the outside line and lowering the inside ?*

8. *How do you introduce the superelevation on the main lines in stations when part of the fast trains run through the stations without stopping ?*

9. *How do you arrange the superelevation on a curve of different radii particularly on the connections between curves of different radii ?*

10. *How do you arrange the superelevation on the short intermediate straight sections between curves in the same direction ?*

11. *How do you carry out the superelevation on curves on double track lines*

Table IV/1.

ADMINISTRATIONS.	Questions 3 and 4. FORMULA.	Question 4. h max. (in mm.).	Question 4. The superelevation is calculated according to the maximum running speed authorised.	Question 4. The superelevation is calculated according to an average running speed.	Question 6. Variations allowed in the amount of superelevation (in ± mm.).	Question 7. The superelevation is generally obtained by raising the outer line of rails.	Question 7. The superelevation is generally obtained by partly raising the outer line of rails and partly lowering the inner line.
BELGIUM.							
Belgian National Railway Company.	For $V \leqslant 70$ km./h. . . . $h = 11.78 \frac{V^2}{R}$. For $V > 70$ km./h. . . . $h = 11.78 \cdot \frac{70}{R} \cdot V$.	150	/	—	+ 20 mm. — 10 mm.	/	—
EGYPT.							
State Railways	$h = \frac{1\,000 \cdot a \cdot V^2}{127\,R}$, in which a = gauge.	120	/	—	—	/	—
FRANCE and COLONIES.							
State Railways	$h = \frac{C}{R} \cdot$ C being a variable co-efficient; C = 40, 50, 60, 75, 90, 105.	150	from experience.		15 mm. in the case of curves of > 500 m. radius; 10 mm. in the case of curves of < 500 m. radius.	/	—
Alsace-Lorraine Railways .	$h = \frac{C}{R} \cdot$ C = Co-efficient varying according to the maximum speeds. 1st class . . C = 85. 2nd class . . C = 66. 3rd class . . C = 50.	144	/	—	Variations due to gradients over 1 in 500 are avoided.	/	—
Est Railway	$h = \frac{12\,V_1^2}{R}$ taking on level sections and falling gradients : $V_1 = 20 + \frac{2}{3} V$.	150	/	—	+ 5 mm. — 5 mm.	/	—
Midi Railway	$h = 11.8 \cdot \frac{a^2}{R}$, $a = 0\ 71$; V = 85, 75, 65, 55 or 45. V = Actual maximum speed.	170	—	/ (V = 71 % of maximum speed).	Between 2 points distant 3 m. or less the superelevation must not be over 2 mm. per metre (1 in 500).	/	—
Nord Railway	$h = \frac{C}{R}$; C is a parameter, the value of which is taken between 40 and 120 according to the traffic on the line.	200	/	—	The superelevation must be corrected when, between 2 points distant at least 3 m. from each other, the relative difference of level of the lines of rails exceeds 12 mm. (i. e. 1 in 250).	—	The inner line of rails is raised and the outer line is lowered, each by half the amount of the superelevation to be obtained.
Paris-Orleans Railway . .	$h = 11.8 \frac{V^2}{R}$. Class . . . . . 1st 2nd 3rd Limiting speed between . . . . . 120÷105 105÷90 90—75 Speed V for which the superelevation is calculated $\frac{85}{R}$ $\frac{75}{R}$ $\frac{65}{R}$	147	—	/	+ 10 mm. — 10 mm.	/	—
Paris-Lyons-Mediterranean Railway.	For $V \leqslant 78$ km./h. . . . $h = \frac{V - 25}{R}$, for $V > 78$ km./h. . . . $h = 1.6 \cdot \frac{V - 45}{R}$.	160	/	—	—	/	—
State Railways in Algeria.	For $V \leqslant 80$ km./h. . . $h = \frac{V - 20}{R}$, for $V > 80$ km./h. . . . $h = 1.5 \frac{V - 40}{R}$.	150	/	—	—	/	—
Moroccan Railways . . .	$h = \frac{2}{3} \cdot \frac{V}{R}$.	—	—	—	± 5 mm.	/	—
ITALY.							
State Railways	$h = 11.78 \frac{V^2}{R}$.	140	—	V = 85 % of maximum speed).	± 10 mm.	/	—
LUXEMBURG.							
Prince Henri Railway . .	$h = 12 \frac{V^2}{R}$.	137	/	—	+ 10 mm. — 15 mm.	/	—
POLAND.							
State Railways	For speeds of 50 km./h. and under, the superelevation is calculated according to the formula $= 11.8 \frac{V^2}{R}$. For speeds over 50 km./h., the superelevation is calculated according to the formula $h = 600 \frac{V}{R}$.	For V = 50 R = 200 150	—	/	+ 5 mm. — 5 mm.	/	—
RUMANIA.							
State Railways	$h = \frac{V}{2R}$ For curves of < 400 m. radius, the superelevation results from practical experiments.	120 / for R — 250 and V = 60 km./h.	/	—	+ 7 mm. — 7 mm.	The outer line of rails is partly raised and the inner line partly lowered.	
CZECHOSLOVAKIA.							
State Railways	Standard superelevation : for $V > 1.971 \sqrt{R}$ ... $h = 46.514 \frac{V}{\sqrt{R}} - 45.384$; for $V < 1.971 \sqrt{R}$ ... $h = 11.8 \frac{V^2}{R}$. Minimum superelevation : for $V > 1.31 \sqrt{R}$ ... $h = 30.926 \frac{V}{\sqrt{R}} - 20.263$; for $V < 1.31 \sqrt{R}$ ... $h = 11.8 \frac{V^2}{R}$. Recently, as a trial : $h = 8 \frac{V^2}{R}$.	142	/	—	+ 5 mm. — 5 mm.	/	—
JUGOSLAVIA.							
State Railways	$h = 11.8 \frac{(a \cdot V)^2}{R}$, $a = 0.8$ for V = 45 ÷ 90 km./h.	109	—	/ (= 80 % of maximum speed).	—	/	—

Table IV/2.

Question 2.

ADMINISTRATIONS.	Speed, m km. per hour.	Superelevation in millimetres — Radius of curves, in metres.																												
		200	250	300	350	400	450	500	550	600	700	750	800	900	1 000	1 100	1 200	1 250	1 300	1 400	1 500	1 600	1 700	1 750	1 800	1 900	2 000	2 200	2 400	2 500
BELGIUM.																														
Belgian National Railway Company.	80						146	133	120	110	95		82	75	66		55			47		41			37		33			29
	90							149	135	124	107		93	82	75		62			53		46			41		37			33
	100								150	137	119		103	92	83		69			59		51			45		41			37
	110									150	131		113	101	91		75			64		57			50		46			42
	120										142		122	110	99		82			70		62			55		50			46
EGYPT.																														
State Railways																														
FRANCE and COLONIES.																														
State Railways																														
Alsace-Lorraine Railways .	80				143																									
	90					125																								
	100							132																						
	110									142	121		106	94	85		70				57						42			34
Est Railway	80																													
	90							150																						
	100									150																				
	110										149																			
	120												150																	
Midi Railway	60, $a = 45$	119	96	80	68	60	53	48	43	40	36		30	27	24		20			17			14				12			10
	75, $a = 55$	178	143	119	102	89	79	71	65	59	51		45	40	36		30			25			21				18			15
	90, $a = 65$			166	142	125	111	100	91	83	71		62	55	50		42			36			29				25			20
	105, $a = 75$					166	148	133	121	111	95		83	74	66		55			47			39				33			27
	120, $a = 85$							171	155	142	122		107	95	85		71			61			50				43			34
Nord Railway																														
Paris-Orleans Railway . .	60 excl. — 75		144	120	103	90	80	72		60	51		45	40	36	33	30		28	26	24						18			
	75 " — 90				143	125	111	100		83	71		62	56	50	45	42		38	36	33						25			
	90 " — 105						147	132		110	94		82	73	66	60	55		51	47	44						33			
	105 " — 120									147	121		106	94	85	77	71		65	61	57						42			
Paris-Lyons-Mediterranean Railway.	80					140																								
	90							144																						
	100									147																				
	110										149																			
	120												160																	
State Railways in Algeria.	80					150		120		100	85		75	65	60						40						25			20
	90							150		125	110		95	85	75						50						30			25
	100									150	130		110	100	90						60						35			30
	110										150		130	115	105						70						40			35
Moroccan Railways . . .																														
ITALY.																														
State Railways	80					140	120	110	100	90	80	70	70	60	50	50	50		40	40	40	30	30		30	30	30			20
	90							140	130	120	100	100	90	80	70	70	60		60	50	50	50	40		40	40	40			30
	100									120(2)	110	100	100	90	80	70	60		60	50	50	50	50		40	40	40			30
	110												120	100	90	80	80		70	70	60	60	50		50	50	50			40
	120														110	100	90		90	80	70	70	70		60	60	60			40
LUXEMBURG.																														
Prince Henri Railway . .	80								137	126	108		94	84	76	69	66		58	54	50	47	44		42	39	38			30
	90																													
	100																													
	110																													
POLAND.																														
State Railways	80							95		80	70		60	55	50	45	40		35	35	30	30	30		25	25	25	20	20	20
	90										75		70	60	55	50	45		40	40	35	35	30		30	30	25	25	25	25
	100													65	60	55	50		45	45	40	40	35		35	30	30	25	25	25
	110																													
RUMANIA.																														
State Railways	80						90	80	65		55		50	45	40	35	35		30	30	25						20			
	90										65		55	50	45	40	40		35	30	30						25			
	100													55	50	45	40		40	35	35						25			
	110															50	45		40	40	35						30			
CZECHOSLOVAKIA.																														
State Railways	80				(1)	140/104	130/96	121/90	113/85	106/81	95/73	91/70	86/67	78/62	72/58			59/50			50/44			43			38			30
	90							141/104	132/98	125/93	112/85	107/82	102/78	94/73	87/68			73/58			62/52			54/46			48/43			38
	100										130/97	125/93	119/89	109/83	101/78			86/67			74/60			65/54			58/49			47
	110													124/93	116/87			90/76			86/68			76/61			69/56			56/48
JUGOSLAVIA.																														
State Railways	80						107	97		81	69		60	54	48			39			32			28			24			
	85							109		91	78		68	61	55			39			32			35			31			
	90									102	87		76	68	61			49			41									
	100																													

(1) Maximum superelevation/minimum superelevation. — (2) For 650 m. radius.

at important level crossings with automobile traffic ?

12. *Is the object of the superelevation obtained by equalising as fully as possible the centrifugal force of trains running at high speeds or do you consider it desirable to alter the amount of the superelevation from this point of view ?*

13. *Is it desirable to reduce the superelevation on short curves in order to restrict the rolling of the vehicles ?*

* * *

Questions 1 to 4. — See tables IV/1 and IV/2.

Question 5. — In principle the maximum limiting speed or an average speed is taken as the basis for calculating the values of the superelevation. If necessary actual values are used. Superelevation is decreased, for example, on certain junctions in stations and when a line has a predominating number of heavy slow trains with which experience has shown that the inside rail wears more quickly than the outside rail. The Czechoslovakian State Railways in certain cases allow the use of so-called minimum values. (See table IV/2.)

The minimum values are used exceptionally when the heavy slow train traffic exceeds the fast train traffic, or on curves on the open road between stations and the covering signals, and all station sidings.

Questions 6 and 7. — See table IV/1.

Question 8. — Most of the administrations superelevate the principal lines in the stations run over by fast trains which do not stop, and the curves on the open road, according to the actual maximum speeds.

Question 9. — The connection of the superelevations between curves of different radii is generally carried out in such a way that it varies proportionally with the curvature. A superelevation gradient between the straight line and the curve is used. The Paris-Orleans Company for example uses a maximum slope of 1 in 500 on the length of the parabolic connections between curves, but an endeavour is being made to reduce this value to 1 in 1 000 on lines run over by high-speed trains.

Question 10. — As a general rule, in short straight sections between curves in the same direction when close together, the line is superelevated, the superelevation varying progressively from the value corresponding to the curve of greater radii to that corresponding to the curve of the smaller radius. For example, the Paris-Orleans Company connects by a continuous gradient the ends of the outside lines of rail of the two curves. The Prince Henri Railways and the Jugoslav State Railways follow the prescriptions of the German Railroad Association according to which, in the case in which the intermediate straight section cannot exceed in length 30 m. (98 1/2 feet) it is recommended that the same superelevation as on the curve of the larger radius be used. The Czechoslovakian State Railways require in cases where the length of the straight section is less than 20 m. (66 feet) that the intermediate straight section shall have 1/3rd of the superelevation of the curve of smaller radius. These 3 different methods are illustrated in figure IV/1.

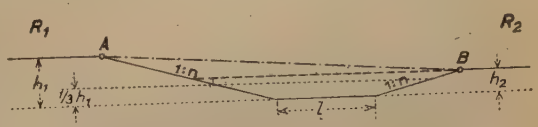


Fig. IV/1.

Question 11. — The increase in the road motor traffic crossing double or multiple track railway lines also demands greater care as regards the superelevа-

tion of the outside rails in the interest of regular road and railway operation. Some administrations have issued in this respect special prescriptions; for example the Paris-Lyons & Mediterranean Company uses the method of arranging the level crossings shown in figures IV/2, 3, and 4.

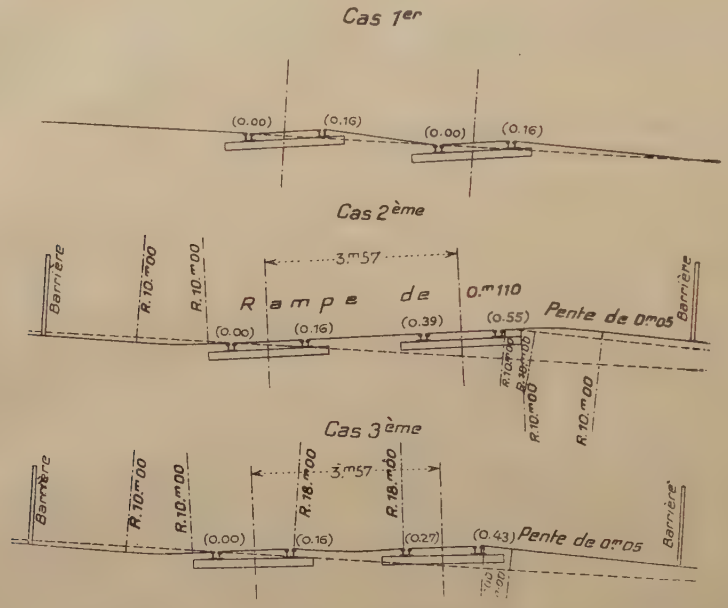


Fig. IV/2, IV/3 and IV/4.

Note : Rampe de... = Rising gradient of... — Pente de... = Falling gradient of... — Barrière = Gate.

Most of the railways deal with level crossings with double track lines in such a way that the running surfaces of the four rails are placed on a single inclined plane. Certain other railways deal with the question according to the local conditions.

Question 12. — The regulations on the superelevation of the outside rail of the different administrations varies (see table IV/2). We may be permitted to add to the main question of the superelevation of the outside rail certain personal remarks.

The superelevation of the outside rail on curves is introduced to compensate the effect of the radial forces, the other forces being neutralised by the reactions in the opposite direction. These reactions are the transverse friction, the reaction which the outside rail offers, against which the flange of the wheel coming into contact with the outside rail bears in a horizontal direction, etc. In order to be able to solve the problem of the superelevation of the outside rail theoretically, it is first of all necessary to appreciate the nature of the forces which act at the contact of the wheels with the rails, the magnitude of these forces and of the reciprocal ratio between them during the various phases of the movement of the vehicle through the curves. Only after these conditions have been studied can the calculation

of the superelevation on curves be taken in hand. The problem of the superelevation of the outside rail is also correlated with other questions concerning the curves, such as the friction on the curves, the gauge widening, etc. The problem in question is closely connected in particular with the gauge widening as the value of the gauge widening depends upon the contact angle α which plays in its turn an important part when calculating the magnitude of the radial forces which will be considered later on.

As a general rule, the superelevation of the outside rail only compensates the centrifugal force without regard to the other radial forces, and the value of the superelevation is calculated according to it. According to this principle, the superelevation depends solely upon the running speed of the train, upon the radius of the curve and upon the gauge of the track. The investigations into the amount of the superelevation made it necessary to examine what other factors should be taken into account in the calculation. This is why it is desirable first of all to ask the more general question as to how the track and vehicles are to be fitted out so that, having taken into account the radial forces in play, the safety when running shall be the same on curves as on the straight. The first condition is undoubtedly safety of running to which we then have to add that of comfortable running and, from the technical and economic point of view, that of practically equal distribution of the vertical wheel loads on the outside rail and even on the inside rail. We will indicate subsequently to what extent these conditions can be best satisfied.

The formulæ in use up to the present for the amounts of the superelevation are based, either on the theoretical formula derived from the centrifugal force with certain reductions — the result of experience — or these formulæ are purely empirical (see table IV/1).

The theoretical formula considering the vehicle as the rigid system is expressed as follows :

$$h = a \tan \varepsilon$$

$$\tan \varepsilon = \frac{C}{2Q}$$

$$C = \frac{mv^2}{R}, \quad m = \frac{2Q}{g}, \quad w = \frac{v}{R}$$

$$h = \frac{av^2}{gR} = a \frac{V}{3.6} \cdot \frac{w}{g} = 11.77 \frac{V^2}{R}. \quad \text{(I)}$$

(See figure IV/5.)

in which :

R = the radius of the curve;
C = the centrifugal force;
V = the maximum speed in km./h.;
v = the maximum speed in m./sec.;
Q = the part of the weight of the vehicle carried by one pair of wheels;
a = 1.50 m. the approximate gauge of the track;
g = 9.81 m./sec.;
w = the angular velocity.

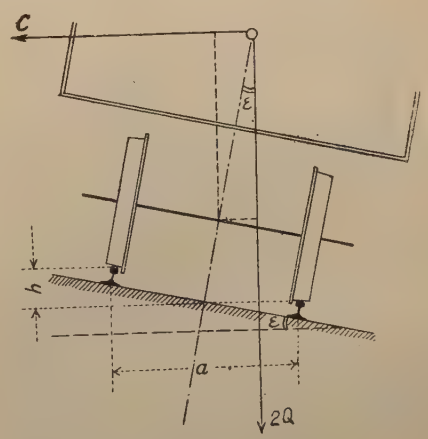


Fig. IV/5.

As regards the speed of the train to be used in the formula, some administrations give an average speed, taking into account the numbers of trains running at the same speeds. Most administrations, however, consider it better to use

in the calculation the actual maximum train speed allowed over a curve of a given radius.

Superelevating the outer rail, while necessary in principle, nonetheless involves certain undesirable consequences. First of all, it means some variation in the standard design of track as in the case of the gauge widening; the tendency is to restrict these variations to the strictly necessary minimum. In some cases a high superelevation has other disadvantages : for example the theoretical formula gives for V = 70 km. (43.5 miles) per hour, and R = 300 m. (15 chains) a normal superelevation $h = 184$ mm. (7 15/64 in.). In this position the inside rail being on a slope of 1 in 20 relatively to the axis of the track inclines towards the inside of the curve by the angle $\varepsilon = \text{arc sin } \frac{h}{a} - \text{arc tan. } \frac{1}{20}$ (See fig. IV/6.)

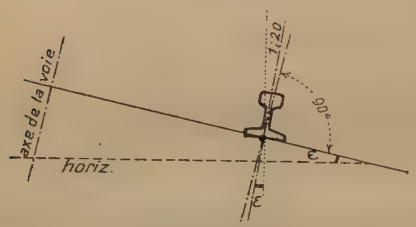


Fig. IV/6.

This tilted position results in the rails or the bearing plates being driven irregularly into the wood sleepers, the rail at the same time twisting, the gauge becoming widened and undesirable stresses being set up in the rail fastenings. Another drawback of excessive superelevation of the outer rail is found in the difficulty in making the roadway at level crossings, particularly when there are two or more tracks.

According to the fundamental theoretical formula I, the value of the superelevation increases in a very considerable manner with the maximum speed, in the absence of any limiting relation between the maximum speed and the maximum radius or of any limit of the maximum superelevation such as, for example, h maximum=0.150 m. (5 29/32 inch). The various fomulæ for the maximum speed are shown in table IV/1.

The calculation of the superelevation of the outer rail according to the formulæ so far in use should serve solely as the basis on which to decide the superelevation, seeing that all the important factors influencing it have not been taken into account. Only a more extended observation of the tracks on curves, as regards maintenance and the wear of the rails, can supply the experience by which to judge if the given superelevation of the outer rail meets the local needs and the conditions considered. For this reason it is not possible to apply in a general way ready made formulæ; it is still necessary to make such adjustment as experience shows to be necessary, at least in cases where the local conditions require it (for example on lines over which trains run at widely differing speeds).

Study of the superelevation.

In the case of vehicles running through curves, the following forces or their components act radially :

the radial component of the tractive effort acting on the draw bar, the horizontal shocks of the tyre flange on the rail, under the action of the undulatory movement of the vehicle (hunting);

the horizontal shocks produced by the unbalanced mass of the revolving and reciprocating parts of the steam locomotives;

wind pressure;

centrifugal force;

the transverse friction of the tyres on the rails in proportion to the perpendicular loads on the wheels;

the horizontal reaction of the pressure of the guiding wheel;

the friction of the springs of the vehicle acting to damp out the dynamic forces of the spring borne mass.

The following factors also influence the value of these different forces.

From the point of view of the *design of the track :*

Value of the radius of the curve, of the superelevation, of the gauge widening, and of the sliding friction constants.

From the point of view of the *design of the vehicle :*

Position of the centre of gravity of the spring borne mass and that unsprung, arrangement of the springs, value of the coefficient of flexibility of the springs, value of the possible transverse displacement of the axle journals in the axle boxes and the arrangement of the couplings.

From the *operating* point of view : the train speed.

In considering the superelevation on curves, it is necessary to include in the calculation, in addition to the centrifugal force, the influence of friction. The effect of the wind only enters into consideration when considering the stability of the vehicle on the track.

When investigating the ratios of the forces acting between the tyre and the rail, and in order to deduce therefrom a more accurate formula for the superelevation of the outer rail, we should note the two characteristic positions of the vehicle on the curve, i. e. the *oblique* position with the tyre coming into contact with the outer rail at a rather considerable angle and the *symmetrical* position at right angles to the longitudinal axis of the vehicle, a position approximating to the tangent TT′ (fig. 7). In the first position the outer guiding wheel touches the outside rail; in the second position the tyres of the outer pairs of wheels touch the outside rail.

a) *Vehicle in an oblique position.*

In the oblique position the centrifugal force, acting on the centre of gravity of the vehicle considered as the rigid system and endeavouring to turn it about the point of contact of the guiding wheel, overcomes first of all the sliding friction on the upper surfaces. It is clear that the turning of the vehicle occurs when the centrifugal force reaches a given value resulting from the speed of the vehicle and inversely proportional to the radius of the curve.

In order to bring out clearly the ratios of the horizontal forces acting here, their directions are given in the drawing of figure IV/7. Let us see under what conditions it is useless to give any superelevation to the outer rail, i. e.

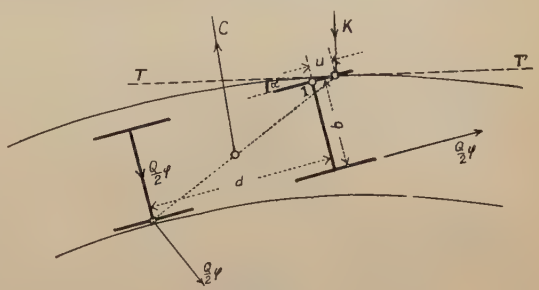


Fig. IV/7.

when the value of the centrifugal force is completely compensated for by the friction. We will evaluate the value of the centrifugal force C by getting out the condition of equilibrium of rotation of the vehicle round the vertical axis of rotation at point 1.

$$C\frac{d}{2} - \frac{Q}{2}\varphi\ d + \sqrt{d^2 + b^2} + b) + Ku = 0.$$

The arm u of the force K is very small and consequently we can neglect the term Ku.

$$\frac{C}{Q} = \varphi\left(1 + \frac{b}{d} + \sqrt{1 + \frac{b^2}{d^2}}\right) \quad \text{(II)}$$

Let us consider the most unfavourable case, i. e. that in which the frictional resistance is lowest. This is the case

when $\varphi = 0.065$ (when the rail head is covered with frost). The relative value of C/Q is smaller as d is greater. Let us therefore select $d = 10$ m. (32 ft. 9 3/4 in.).

$\frac{C}{Q} = 0.14$, which corresponds to :

$$\tan \varepsilon' = \frac{C}{2Q} = 0.07;$$

$h' = a \tan \varepsilon' = 105$ mm. (4 1/8 in.).

It would therefore be possible to reduce the value of the superelevation h resulting from the formula I by the value $h' = 105$. The effect of the sliding friction resistance therefore shows itself in this sense that the angle ε can be reduced by the value ε'. For reasons of safety it is always possible to allow only half the value h' and ε' for the reduction of the superelevation h and of the angle ε which gives us the formula :

$$h = 11.77 \frac{V^2}{R} - 52 \quad . \quad . \quad \text{(III)}$$

and when $h = 0$

$$\frac{V^2}{R} = 4.4 \quad . \quad . \quad . \quad . \quad \text{(IV)}$$

This is true for example when R = 500 (25 chains), V = 47 km. (29.2 miles) per hour, i. e. the highest speed for which when taking the frictional resistance in account, it would not be necessary to superelevate the outer rail on a curve.

This examination shows that if the vehicle, with the trailing pair of wheels clear of the outer rail, has to turn about the point of contact of the outer wheel of the guiding pair with the outer rail, the resistance due to the sliding friction requires a large part of the centrifugal force to overcome it. Consequently the movement of rotation only arises at rather high running speeds. As soon as the vehicle occupies the symmetrical position in which the angle of contact α is smallest, there is no longer any transverse sliding frictional resistance.

Consequently formula (III) is not usable for high train speeds.

b) *Vehicle in symmetrical position.*

When the vehicle pushes against the outer rail, as occurs especially at high speeds through the excess centrifugal force, the pressures are distributed over the two outer pairs of wheels, and the rail then resists through the reactions A and B (see fig. IV/8).

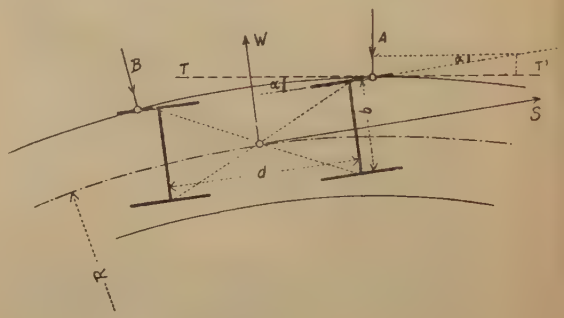


Fig. IV/8.

We ought to distribute the wheel loads and centrifugal force after having taken into account the springs.

The height of the centre of gravity of the spring supported mass and the coefficient of flexibility of the spring have also to be taken into account.

Let us take for the cases considered later on the same designations :

Q_1 weight of half the unsprung mass of the vehicle;

Q_2 weight of half the sprung mass of the vehicle;

C_1 centrifugal force acting on the unsprung mass;

C_2 centrifugal force acting on the spring borne mass;

Ee the live load on the spring on the outside of the curve = Ji, the reduction of load on the inside spring on the curve;

E reaction of the sprung mass on the outer spring;

J reaction of the sprung mass on the inside spring;
H wind pressure on the body = 136 f in kgr., f being the area of the body in m²;
$W = C_2 + H$;
a normal distance between the rail centres;
m distance between the centres of the springs;
n height of the centre of gravity of the sprung mass above the axis of rotation θ;
s height of the centre of gravity of the sprung mass above the rail;
$\varkappa$ static deflection of the spring under the weight $\frac{Q2}{2}$;
η deflection of the spring under the weight $\frac{E\text{-}J}{2}$;
g acceleration due to gravity = 9.81;
r radius of the wheel;
R radius of the curve;
Ψ angle of inclination of the sprung mass under the action of the force W acting on the vehicle;
h superelevation of the outside rail.

Let us consider several cases.

First case : Vehicle being in a position of equilibrium as regards turning over (Equilibrium of the wheels relatively to the point e if we take the superelevation $h = \theta$ (fig. IV/9).

Let us consider, for example, an eight-wheeled rail motor coach 19.50 metres long and a body 3 metres high, total tare weight of the vehicle 34 000 kgr.

$$\left.\begin{array}{l} Q_1 = 6\,500 \text{ kgr.} \\ Q_2 = 10\,500 \text{ kgr.} \end{array}\right\} Q = 17\,000 \text{ kgr.}$$

$$\varkappa = 0.06 \frac{Q_2^{(t)}}{2} = 0.06 \frac{10.5}{2} = 0.315$$

$m = 1.975$ m.
$a = 1.50$ m.
$r = 0.50$ m.
$n = 1.45$ m.
$s = 2.42$ m.

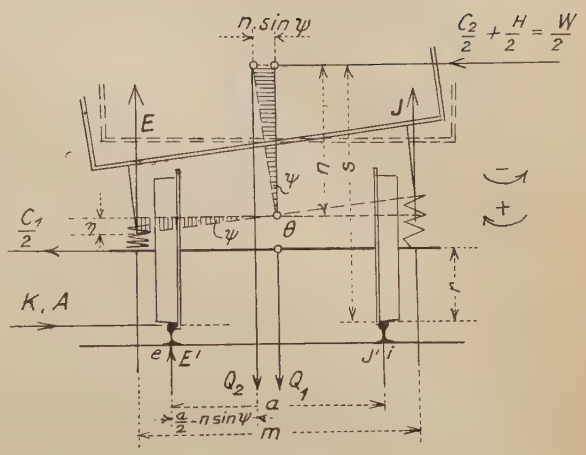


Fig. IV/9.

Let us write down the coefficients :

$$w = \frac{H}{2Q} = \frac{19.5.3.136}{2.17000} = 0.234$$

$$z = \frac{n^2 \varkappa}{\frac{m^2}{4} - n\varkappa} = 1.278$$

$$\left.\begin{array}{l} E = \frac{Q_2}{2} + E_e \\ J = \frac{Q_2}{2} - J_i \end{array}\right\} E_e = J_i = \frac{E - J}{2}$$

$$\frac{W}{2} = \frac{C_2}{2} + \frac{H}{2} = \frac{Q_2 v^2}{g R} + \frac{136 f}{2} =$$

$$\frac{Q_2 v^2}{g R} + w Q_2 = \frac{Q_2}{g R}(v^2 + wg R).$$

$$w = \frac{136 f}{2 Q}$$

$$\frac{C_1}{2} = \frac{Q_1 v^2}{g R}, \frac{C_2}{2} = \frac{Q_2 v^2}{g R}, W = \frac{2 Q_2}{g R}(v^2 + wg R).$$

Calculation of the sin Ψ for the condition of equilibrium at point θ :

$$\frac{W}{2} n + Q_2 n \sin \Psi - E \frac{m}{2} + J \frac{m}{2} = 0.$$

$$W n + 2 Q_2 n \sin \Psi - m (E - J) = 0.$$

Calculation of η (i. e. of the deflection of the spring caused by the live load E_e

the deflections η and $\varkappa$ are in the proportion of the forces producing them):

$$\eta : \varkappa = E_e : \frac{Q_2}{2} = \frac{E - J}{2} : \frac{Q_2}{2} = \frac{E - J}{Q_2},$$

$$\eta = \frac{E - J}{Q_2}\varkappa.$$

$$E - J = \frac{Q_2 \eta}{\varkappa}, \quad E + J = \frac{Q_2}{2} + E_e +$$

$$+ \frac{Q_2}{2} - J_i = Q_2.$$

Ratio between η and $\varkappa$ (see the dotted triangle):

$$\eta = \frac{m}{2}\sin\Psi$$

$$n\sin\Psi - \frac{m(E - J)}{2Q_2} = -\frac{Wn}{2Q_2}$$

$$n\sin\Psi - \frac{m}{2}\cdot\frac{n}{\varkappa} = -\frac{Wn}{2Q_2}$$

$$-n\sin\Psi + \frac{m}{2}\cdot\frac{m}{2}\sin\Psi\frac{1}{\varkappa} = \frac{W}{2Q_2}n$$

$$\sin\Psi = \frac{n\varkappa}{\frac{m^2}{4} - n\varkappa}\cdot\frac{1}{gR}(v^2 + wgR)$$

Let us take moments relatively to e:

$$-J'a - \frac{C_1}{2}r - \frac{W}{2}s + Q_1\frac{a}{2} + Q_2$$

$$\left(\frac{a}{2} - n\sin\Psi\right) = 0$$

$$-J'a - \frac{Q_1 v^2}{gR}r - \frac{Q}{gR}(v^2 + wgR)s +$$

$$+ Q\frac{a}{2} - Q_2\frac{n^2\varkappa}{\frac{m^2}{4} - n\varkappa}\cdot\frac{1}{gR}(v^2 + wgR) = 0$$

$$-J'a - \frac{Q_1 v^2}{gR}r - \frac{Q^2}{gR}(v^2 + wgR)s +$$

$$+ Q\frac{a}{2} - Q_2 z\frac{1}{gR}(v^2 + wgR) = 0.$$

The condition of turning over occurs if we take $J' = 0$ Seeing that for equilibrium we can also apply the equation :

$$E' + J' = Q_1 + Q_2 = Q,$$

we have :

$$E' = Q_1 + Q_2 = Q.$$

The critical speed

$$v = \sqrt{\frac{(Q_1 + Q_2)\frac{a}{2} - Q_2(s + z)w}{Q_1 r + Q_2 s + Q_2 z}gR} = \sqrt{0.854\,R} \quad . \quad . \quad . \quad . \quad (V)$$

$$= 0.924\sqrt{R}$$

$$V = 3.6\,v = 3.6\,0.924\sqrt{R} = 3.326\sqrt{R} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (VI)$$

For the practical case when R = 300 m. (15 chains), the condition of turning over would occur for the critical speed :

$v = 0.924 \times 17.3205 = 16.004$ m./sec. (52.507 feet) per second,

$V = 3.326 \times 17.3205 = 57.708$ km. (35.858 miles) per hour.

and when R = 500 m. (25 chains):

$v = 0.924 \times 22.3607 = 20.661$ m. (65.503 feet) per second,

$V = 3.326 \times 22.3607 = 74.371$ km. (46.212 miles) per hour.

Second case : The vehicle in the stable position. The superelevation h balances

the effect of the centrifugal force. The pressure of the wind is not considered in this connection (fig. IV/10).

Let us take moments relatively to e :

$$-J'a\cos\varepsilon-\frac{C_1}{2}\left(r\cos\varepsilon-\frac{a}{2}\sin\varepsilon\right)-\frac{C_2}{2}\left(s\cos\varepsilon-\frac{a}{2}\sin\varepsilon\right)+Q_1\left(\frac{a}{2}\cos\varepsilon+r\sin\varepsilon\right)+$$
$$+Q_2\left(\frac{a}{2}\cos\varepsilon+s\sin\varepsilon-n\sin\Psi\right)=0$$

If we put $\cos\varepsilon=1$, $\sin\varepsilon=\tan\varepsilon$

$$-J'a-\frac{C_1}{2}\left(r-\frac{a}{2}\tan\varepsilon\right)-\frac{C_2}{2}\left(s-\frac{a}{2}\tan\varepsilon\right)+Q_1\left(\frac{a}{2}+r\tan\varepsilon\right)+$$
$$+Q_2\left(\frac{a}{2}+s\tan\varepsilon-n\sin\Psi\right)=0$$

$$-J'-\frac{C_1}{2}r-\frac{C_2}{2}s+\frac{Q_1}{2}a+Q_2\left(\frac{a}{2}-n\sin\Psi\right)+\frac{C_1}{2}\frac{a}{2}+\tan\varepsilon\,\frac{C_2}{2}\frac{a}{2}\tan\varepsilon+$$
$$+Q_1r\tan\varepsilon+Q_2s\tan\varepsilon=0$$

$$-J'a-\frac{C_1}{2}r-\frac{C_2}{2}s+Q_1\frac{a}{2}+Q_2\left(\frac{a}{2}-n\sin\Psi\right)+\left[\frac{C_1}{2}\frac{a}{2}+\frac{C^2}{2}\frac{a}{2}+Q_1r+Q_2s\right]\tan\varepsilon=0$$

If we put $\cos n \sin\Psi = z$ $\dfrac{v^2}{gR}$

$$-2J'agR-2Q_1v^2r-2Q_2v^2s-(Q_1+Q_2)agR-2Q_2zv^2+[Q_1v^2a+Q_2v^2a+$$
$$+(Q_1r+Q_2s)2gR]\tan\varepsilon=0$$

$$v^2(2Q_1r+2Q_2s+2Q_2z-Qa\tan\varepsilon=-2J'agR+QagR+(Q_1r+Q_2s)2gR\tan\varepsilon$$

$$v^2=\frac{-2J'agR+QagR+(Q_1r+Q_2s)2gR\tan\varepsilon}{2Q_1r+2Q_2s+2Q_2z-a\tan\varepsilon Q}$$

If we put : $2Q_1r+2Q_2s+2Q_2z=Z$.

$$Zv^2-Qv^2a\tan\varepsilon=-2J'agR+QagR+(Q_1r+Q_2s)2gR\tan\varepsilon$$

$$\tan\varepsilon=\frac{h}{a}=\frac{v^2Z+gR(2aJ'-Qa)}{v^2aQ+2gR(Q_1r+Q_2s)}$$

$$h=a\,\frac{v^2Z+gR(2aJ'-Qa)}{v^2aQ+2gR(Q_1r+Q_2s)} \qquad \text{(VII)}$$

For the formula for the superelevation to be usable in practice, the algebraic values must be replaced by the actual numerical values. With this object we will use the data relative to the first driving pair of wheels of locomotive type 387-0 with a very high centre of gravity of the spring carried mass :

$Q_1 = 3.850$ kgr.
$Q_2 = 13.050$ kgr.
$m = 1.10$ m.
$r = 0.95$ m.
$s = 2.66$ m.
$\varkappa = 0.0083 \cdot \dfrac{Q_2}{2} = 0.054$
$a = 1.50$ m.
$n = 0.82$ m.

$$z=\frac{n^2\varkappa}{\frac{m^2}{4}-n\varkappa}=0.14$$

$$Z=2Q_1r+2Q_2s+2Q_2z=80.395$$

$$h=\frac{4.76v^2+29.43R\dfrac{J'}{Q}-14.715R}{v^2+29.7R} \qquad \text{(VIII)}$$

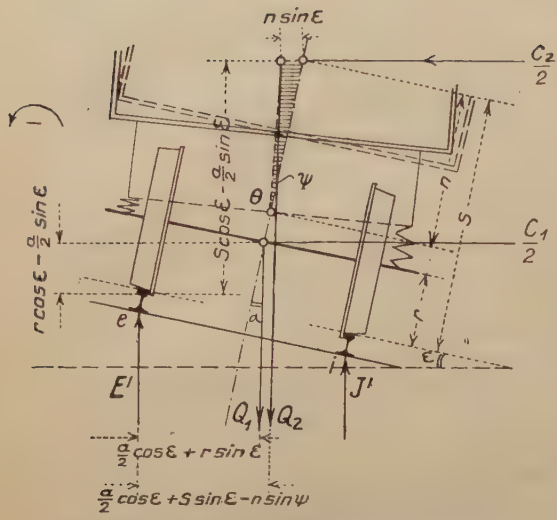


Fig. IV/10.

As formula (VIII) shows, h depends upon the speed, the radius of the curve, and in addition upon the ratio $\frac{J'}{Q}$. We will select the value of this ratio according to the condition we have supposed as regards the direction of the resultant of the reactions of the rails. If in an extreme case the resultant of the forces acting on the vehicle should be perpendicular to the plane of the sleepers and pass through the point o, the ratio $\frac{J'}{Q} = 1/2$.

According to formula (VIII), the value h would be too high. This is why, as a rule, it is not possible to insist on this condition, and it is necessary to admit that the resultant at the level of the sleepers intersects at some point e on the outside of the centre line of the track. If we take $J' = \phi$, we get the case of equilibrium of turning over, i. e. a case that cannot be allowed. This case could possibly happen with a lower superelevation through wind pressure. This is why it is necessary to consider at the same time the stability of the vehicle under wind pressure $H = 136\ f$ in which f is the surface in m² upon which the wind pressure acts; the pressure of 136 kgr. per m² (27.85 lb. per sq. foot) corresponds to a wind speed of 120 km. (74.6 miles) per hour. To consider the stability of the vehicle against turning over in the direction of the centrifugal force in the equation of the moments the value $\frac{C_2}{2}$ is replaced by the value

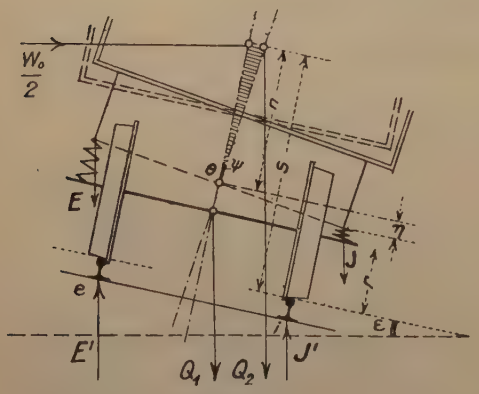


Fig. IV/12.

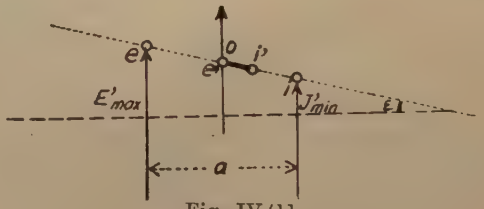


Fig. IV/11.

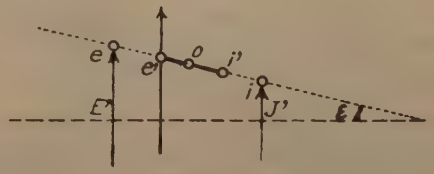


Fig. IV/13.

$\frac{W}{2} = \frac{C_2}{2} + \frac{H}{2}$ and we then get the equation :

$$h = a\frac{v^2 Z + gR\,[2aJ' + 2Q_2 w\,(s+z) - Qa]}{v^2 aQ + 2gR\left(Q_2\frac{a}{2}\,w + Q_1 r + Q_2 s\right)}$$

If we replace h by the value from formula (VIII), it is possible to calculate and examine J'. If $J' > 0$, the stability is maintained.

In the same way it is desirable to consider the stability of the vehicle against turning over towards the centre of the curve under the action of the wind, when the vehicle is standing, on the inclined plane towards the centre of the curve, i. e. on taking $V = 0$ (see fig. IV/12). Here again we suppose an extreme case in which the friction of the tyre on the rails is eliminated and in which the flanges of the inside wheels touch the inside rail. From the condition of equilibrium relatively to the point i, we get

$$E'a\cos\varepsilon + wQ_2 s\cos\varepsilon + wQ_2\frac{a}{2}\sin\varepsilon - Q_1\frac{a}{2}\cos\varepsilon + Q_1 r\sin\varepsilon - Q_2\frac{a}{2}\cos\varepsilon + $$
$$+ Q_2 s\sin\varepsilon + Q_2 n\sin\Psi = 0$$

$$E'a + wQ_2 s + wQ_2\frac{a}{2}\tan\varepsilon - Q_1\frac{a}{2} + Q_1 r\tan\varepsilon - Q_2\frac{a}{2} + Q_2 s\tan\varepsilon + Q_2 n\sin\Psi = 0$$

$$E'a + wQ_2 s - Q_1\frac{a}{2} - Q_2\frac{a}{2} + wQ_2\frac{a}{2}\tan\varepsilon + Q_1 r\tan\varepsilon + Q_2 s\tan\varepsilon + Q_2\frac{zv^2}{gR} + Q_2 wz = 0$$

$$E' = \frac{Q}{2} - \frac{h}{a^2}\left(wQ_2\frac{a}{2} + Q_1 r + Q_2 s\right) - \frac{Q_2}{a}\left(ws + \frac{zv^2}{gR}\right) - \frac{Q_2}{a}wz$$

$$= \frac{Q}{2} - \frac{h}{a^2}\left(wQ_2\frac{a}{2} + Q_1 r + Q_2 s\right) - \frac{Q_2}{a}ws - \frac{Q_2 z v^2}{agR} - \frac{Q_2}{a}wz$$

$$E' = \frac{Q}{2} - \frac{h}{a^2}\left(wQ_2\frac{a}{2} + Q_1 r + Q_2 s\right) - \frac{Q_2}{a}ws - \frac{Q_2 z}{a}\left(\frac{v^2}{gR} + w\right)$$

For $v = 0$:

$$E'_{min} = \frac{Q}{2} - \frac{h}{a^2}\left(wQ_2\frac{a}{2} + Q_1 r + Q_2 s\right) - \frac{Q_2}{a}w\,(s+z).$$

In the position of equilibrium of turning over, i. e. when the resultant passes through the point i, E'_{min} will be $= 0$, then

$$h = \frac{\frac{Q}{2} - \frac{Q_2}{2}w\,(s+z)}{wQ_2\frac{a}{2} + Q_1 r + Q_2 s} - a^2$$

$$= \frac{Qa^2 - 2Q_2 aw\,(s+z)}{Q_2 aw + 2Q_1 r + 2Q_2 s}.$$

The most convenient way to proceed is to introduce, as a result of the experience acquired on the tracks with different train speeds, in the calculation as h maximum a given value, for example 150 mm. (5 29/32 inches) [for R = 300 (15 chains), V = 75 km. (46.6 miles) per hour], and then deduce from equation (VIII) the value of the ratio $\frac{J'}{Q} = 0.422$. $\frac{E'}{Q} = 0.578$. The live load on the outer wheel would consequently reach 15.6 %.

Taking for example $\frac{J'}{Q} = 0.42$, we ob-

tain from formula (VIII) the value for h in which the superelevation depends solely on the speed and on the radius of curve :

$$h = \frac{4.76\,v^2 + 29.43\ \mathrm{R}.\ 0\ 42 - 14.715\,\mathrm{R}}{v^2 + 29.7\,\mathrm{R}}$$

$$h = \frac{4.76\,v^2 - 2.3\,\mathrm{R}}{v^2 + 29.7\,\mathrm{R}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (\mathrm{IX})$$

This formula gives the values of the usable superelevation for different speeds and for different radii of curves as shown in the following table :

Radius R, in metres (*in chains*).	Speed in km. (*in miles*) per hour								
	30 (*18.6*)	40 (*24.9*)	50 (*31.1*)	60 (*37.3*)	70 (*43.5*)	80 (*49.8*)	90 (*55.9*)	100 (*62.2*)	110 (*68.3*)
	Speed in m. (*in feet*) per second								
	8.33 (*27.33*)	11.11 (*36.45*)	13.89 (*45.57*)	16.67 (*54.69*)	19.44 (*63.78*)	22.27 (*73.06*)	25.00 (*82.02*)	27 78 (*91.14*)	30.56 (*100.26*)
	Millimetres (*inches*)								
200 (*10*)	...	21 (*53/64*)	74 (*2 29/32*)	139 (*5 15/32*)	...	...	...	...	...
300 (*15*)	...	...	25 (*63/64*)	69 (*2 23/32*)	120 (*4 45/64*)	...	...	...	...
400 (*20*)	...	...	...	33 (*1 19/64*)	72 (*2 53/64*)	115 (*4 33/64*)	...	...	...
500 (*25*)	...	...	..	11 (*7/16*)	43 (*1 11/16*)	78 (*3 5/64*)	118 (*4 5/8*)	...	...
700 (*35*)	...	...	...	...	9 (*23/64*)	35 (*1 3/8*)	64 (*2 33/64*)	96 (*3 25/32*)	135 (*5 5/16*)
1 000 (*50*)	...	...	...	...	...	2 (*5/64*)	22 (*7/8*)	45 (*1 49/64*)	70 (*2 3/4*)

The formula (IX) limits at the same time the superelevation for lower speeds as the following shows :

If we take $h = 0$,

$$4.76\,v^2 - 2.3\,\mathrm{R} = 0.$$

From this ratio we get the following formula :

$$v = \sqrt{0.48\,\mathrm{R}} \quad . \quad . \quad . \quad . \quad (\mathrm{X})$$

which gives the maximum values v for which it is not necessary to superelevate the outer rail on a curve of radius R according to the following summary :

For R :	at a speed of :
200 m. (10 chains) .	$v \leqslant$ 9 75 m. (31.99 ft.) per second, $V \leqslant$ 35 km. (21.7 miles) per hour.
300 » (15 ») .	$v \leqslant$ 12.00 m. (39.37 ft.) » , $V \leqslant$ 43 km. (26.7 miles) » .
400 » (20 ») .	$v \leqslant$ 13.90 m. (45.60 ft.) » . $V \leqslant$ 50 km. (31.1 miles) » .
500 » (25 ») .	$v \leqslant$ 15.45 m. (50.69 ft.) » , $V \leqslant$ 56 km. (34.8 miles) » .
700 » (35 ») .	$v \leqslant$ 18.40 m. (60.37 ft.) » , $V \leqslant$ 66 km. (41.0 miles) » .
1 000 » (50 ») .	$v \leqslant$ 22.00 m. (72.18 ft.) » , $V \leqslant$ 72 km. (44.7 miles) » .

It is advisable to check these results by experimental measurements and by observation.

The preceding considerations bring out clearly the influence of the position of the centre of gravity on the calcula-

tion of the superelevation of the outer rail. It will evidently be necessary to check again the results by experimental tests.

In this part of our report dealing with the superelevation of the outer rail on curves, we have given rather more space to theoretical conditions because we consider as very important the influence of the superelevation in correlation with the position of the height of the centre of gravity of the vehicle with a view to safeguarding safety at high speeds. We would also refer as an example to the report of Colonel Anderson relatively to the causes of the derailment of fast trains, on the 14 January 1930 at Weaver Junction on the London Midland and Scottish Railway, and the 23 January 1930 at Kent House on the Southern Railway (1).

Question 13. — The superelevation on curves of small radius shows itself as a dissymmetrical difference in level of the track, when the length of the curve itself is not at least equal to the length of the transition curve. The superelevation on curves of small radius greatly favours the rolling of the vehicles, especially when the springs are very flexible. This is why the railway administrations avoid using short curves and replace them, where they have to be used, by curves of sufficiently large radius so that it is not necessary to give any superelevation to the outer rail.

V. — Transition curves.

QUESTIONS.

1. *Upon what principles is the transition curve between the straight line and the curve carried out? What form of curve on the horizontal plane is used in this transition (cubic parabola, lemniscate, etc.)?*

2. *How is the equation of the transition curve got out relatively to the axes X and Y, when the axis X is situated on the extension of the straight line?*

3. *How is the transition between the straight and the circular curve in the vertical plane carried out on superelevation gradients (ramps)?*

4. *What is the radius of the circular curve connecting the alterations of slope at the beginning and end of the superelevation gradients?*

5. *What inclination is given to the superelevation gradient?*

Is the inclination of the upward or downward slope to or from the superelevated rail decided by the maximum running speed allowed and by the fact that the position of the vehicle on this slope has no unfavourable action upon the distribution of the wheel loads?

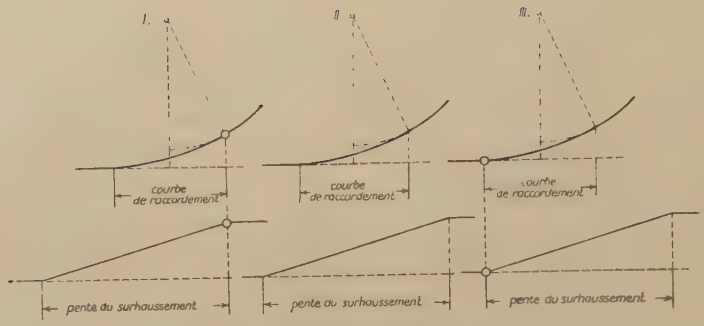
6. *Are the lengths of the transition curve and of the up or down slope to or from the superelevation equal or different?*

7. *How are the transition curves and the up or down slope for the superelevation arranged when the transition curve is shorter than the up or down superelevation gradient (case I, II or III — figure on following page)?*

The rolling line on the outside rail in the connection of one curve to another in the same direction, but with different superelevations is a curve in space. Its extension on the horizontal plane is the equidistant line drawn at a distance $\frac{a}{2}$ along and outside the centre line of the track.

The projection of the axis of the track on the horizontal plane is the *transition curve.* If we consider that the outside rail and the axis of the track form concentric curves while the gauge widening

(1) Cf. *Bulletin of the Railway Congress Association*, September 1931, page 788.



Note : Courbe de raccordement = Transition curve.
Pente du surhaussement = Superelevation gradient.

on curves is generally arrived at by moving the inside rail towards the centre of the curve, we must consider, in order to simplify the calculation and the pegging out, an equidistant curve.

The transition curve is a line of varying curvature, so that at the tangent points, the transition curve and the circular curve have the same tangent and the same curvature.

For the practical application, the equation of the cubic parabola $y = \frac{x^3}{6C}$ is indicated.

It is possible to calculate in each of its points the actual curvature from the formula

$$r = \frac{(1 + y'^2)^{3/2}}{y''}$$

which gives

$$r = \frac{C}{x}\left(1 + \frac{x^4}{4C^2}\right)^{3/2} \quad . \quad (I)$$

In place of the cubic parabola another curve, such as a radiode, lemniscate, or clotoide can be chosen.

Replacing

$$\frac{x^2}{2C} = \tan \alpha$$

we get

$$r = \frac{C}{x}(1+\tan^2\alpha)^{3/2} = \frac{C}{x} \cdot \frac{1}{\cos^3\alpha} \quad . \quad (II)$$

The superelevation gradient between two circular curves is the rolling line of the outer rail extended in the vertical plane (Z, Y). This superelevation gradient must have at each point an ordinate Z equal to the superelevation, inversely proportional to the radius of the transition curve. We consider the transition curve in the axes X, Y, and the superelevation gradient in the axes X, Z.

The requirements of the superelevation will be fulfilled when $z = \frac{k}{r}$, wherein k is the constant depending on the square of the speed v^2. When on a given curve the superelevation is equal to h_1, and the radius of the outer rail r_1, the ordinate $z = \frac{h_1 r_1}{r}$.

If we replace r in the formula

$$z = \frac{k}{r} = \frac{kx}{C\left(1 + \frac{x^4}{4C^2}\right)^{3/2}} \quad . \quad (III)$$

we shall obtain the equation for the superelevation gradient.

By making $z' = \theta$, we get

$$x = \sqrt[4]{\frac{4}{5}C^2} = \xi ;$$

i.e. for

$$x = \xi,\ Z_{max} = 0.7197\,\frac{k}{\sqrt{C}}$$

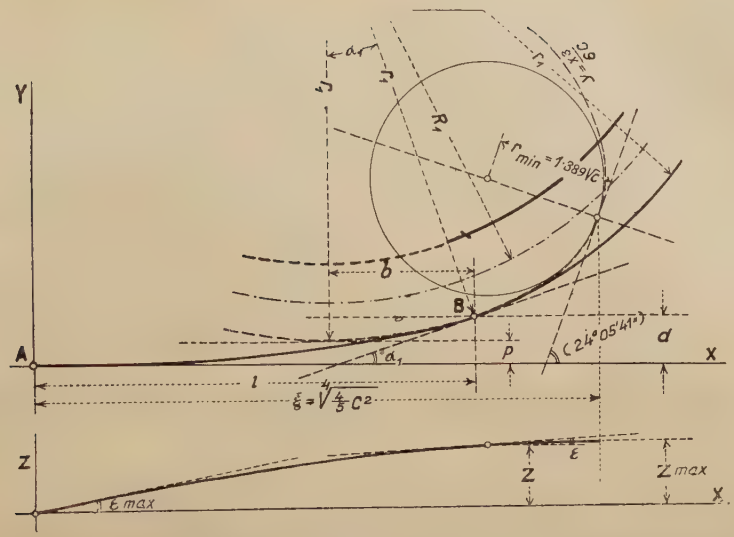


Fig. V/1.

and at the same time tan $\varepsilon = \theta$. For $x = O$, $Z'' = \theta$ and tan ε reaches the maximum value

$$\tan \varepsilon_{max} = 8\, k\, C^2 \cdot \frac{4\, C^2}{(4\, C^2)^{5/2}} = \frac{k}{C}$$

Within the limits $x > \theta$ and $x < \xi$, Z'' gives a negative value and consequently within these limits the curve of the superelevation gradient is concave relatively to the axis X. Its form is shown in figure V/1.

The form of the superelevation gradient given by equation (III) cannot be maintained in practice, as it is too complicated. In addition the dynamic effects on the changing of the profile of the track and in particular the effect of the centrifugal force in the vertical plane in the connection between the gradients and finally the consideration of the adaptation of the vehicles to the differences in level of the track, have to be taken into consideration.

The centrifugal force in the vertical plane transmitted through the wheel to the rail is $P = \frac{mv^2}{\rho}$. This force, as the formula shows, increases inversely with the radius of the curvature on the vertical plane. For $\rho = \theta$ this force would become infinitely great (∞). Consequently, its value can, in practice for high speeds and small curves connecting the gradients, increase in an appreciable measure. This is why these connections between gradients should have quite large radii.

The superelevation gradient can in practice be divided into three parts : the middle part in which the slope reaches its maximum value, and the ends built up of circular curves. For simplification, the connecting line is selected in such a way that the slope may be constant, i. e. it is replaced by a straight line

$$\tan \varepsilon = \frac{z}{\lambda} = \frac{h_1}{\lambda_1} = \frac{h_1}{l},$$

where l is the developed length of the transition curve. We replace the ex-

treme ends by circular curves of a radius greater than 5 000 m. (250 chains) so that the horizontal distance over the tops of the angles is equal to the distance of the tangent points 1-2 of the transition curve (fig. V/2). If the slope of the superelevation is 0.0014 or less, the above connections between the gradients by circular curves can be suppressed.

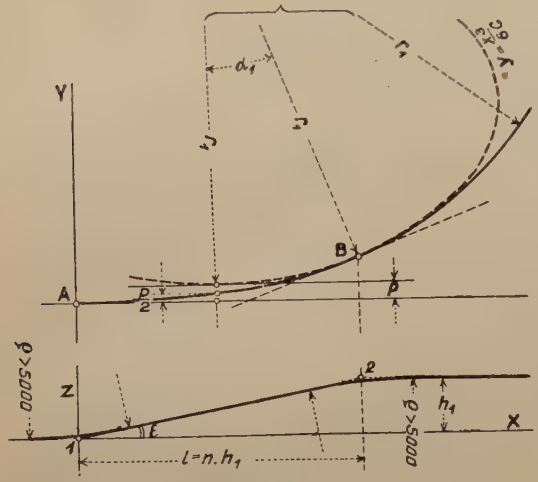


Fig. V/2.

From this fact we get the equality of the length of the transition curve and the superelevation connection. From this formula we find the length 1; we select a suitable slope for tan ε . The slope of the superelevation connection depends upon the speed of the train, seeing that the value h includes the square of the speed v (see IV, Superelevation). Some administrations, for practical purposes, use empirical formulæ for the length. Others, conforming to practical needs, modify the slope of the superelevation according to the maximum allowable speed in km./h.

It must be added that the relation between the maximum speed allowed and the superelevation slope $\frac{h}{l} = \frac{1}{n}$ can be expressed as follows : the speed of the vertical movement of the outside wheel on the superelevation is $\eta_1 = \frac{h}{t}$. During the period of time t, the wheel travels a distance l at the speed V, i.e. $t = \frac{l}{V}$. In these ratios we get $\eta_1 = \frac{V}{n}$.

We may take this value η_1 as being constant. It is desirable to select it within the limits of 1/8 to 1/10. For example, for $\eta_1 = 1/10$, $n = 10$ V, or $l = nh = 10$ Vh for $n = 8$ V, $l = 8$ Vh.

These formulæ, in correlation with the table in the preceding part IV (*Superelevation*), give usable values for both small and high speeds.

For example, for the radius R = 500 (25 chains) we obtain :

Vmax, km. (*miles*) per hour.	h mm. (*inches*).	$l = 10$ Vh m. (*feet*).	$l = 8$ Vh m. (*feet*).
70 (*43.5*)	49 (*1 59/64*)	34.30 (*112.5*)	27.44 (*90.0*)
80 (*49.7*)	91 (*3 37/64*)	72.80 (*238.8*)	58.24 (*191.1*)
90 (*55.9*)	136 (*5 23/64*)	122.40 (*401.6*)	97.92 (*321.3*)

When pegging out the transition curve, the values r, l, C, α must be known: from these latter the other values can be deduced.

As a rule, the radius r_1 and the length of the superelevation connection l, calculated from the maximum allowable speed according to the formula for the slope $l = nh$, is known.

From the formula for the cubic para-

Table V.

ADMINISTRATIONS.	Question 1.	Question 2.	Question 3.	Question 4.	Question 5.
	Principles governing the connection between the straight line and the circular curve.	Formula.	Principle of the superelevation gradient.	Radius of the circular curve by which the graded slopes are connected to the spring or end of rising or falling superelevation gradients.	Inclination of the rising or falling superelevation gradient.
BELGIUM.					
Belgian National Railway Company.	Cubic parabola.	$y = \frac{x^3}{6C}$.	In the vertical plane, the connection between the straight sections and the circular curve are laid out linearly.	No directions.	1 in 2 000 ÷ 1 in 500 (the slope is calculated as a function of the cant and the length of the parabolic arc.
EGYPT.					
State Railways	According to Trautwine's method (Railroad curves).		Do.	Do.	1 in 500
FRANCE and COLONIES.					
State Railways	Cubic parabola.	$y = \frac{x^3}{2\rho R'}$, 2ρ is the abscissa of the point at which the parabolic arc is connected to the arc of circle of reduced radius R'.	Do.	Do.	In principle, the slope is, except when impossible, 1 in 1 000. It should not be over 1 in 666 on lines where trains run at a speed over 100 km./h. and 1 in 500 on other lines.
Alsace-Lorraine Railways .	Cubic parabola.	$y = \frac{x^3}{6C}$, C = l R.	No rules laid down.	R = 5 000 m. on the open main lines, and 2 000 m. in stations and on secondary lines.	On lines run over by express trains, 1 in 1 000 as far as possible, but in no case over 1 in 500. On all other lines, 1 in 300 may be reached.
Est Railway	Cubic parabola.	$y = \frac{x^3}{6\rho\lambda}$, in which ρ is the smallest radius on the line under consideration, λ being a function of the speed V and the slope i; $iV = k$ constant.	In the vertical plane, the transition between the straight sections and the circular curve is laid out linearly.	No circular connecting curves used in the case under consideration.	1 in 625 for speeds up to 60 km./h. and 1 in 909 for speeds up to 120 km./h. Experience has shown that 1 in 500 must be a maximum for superelevation gradients.
Midi Railway	Cubic parabola.	$y = \frac{x^3}{6\rho R}$, in which ρ is the length of the connection, R the radius of the circular curve to be connected.	Do.	No directions as regards the use of a circular connecting curve in the vertical plane at the ends of the connections.	The superelevation gradient varies according to the class of the line. It is: for a = 45, — 1 in 500: for a = 55, — 1 in 500; for a = 65, — 1 in 666: for a = 75, — 1 in 1 000; for a = 85, — 1 in 1 000, wherein a is the average speed.
Nord Railway	Cubic parabola.	Cambier's formula for existing track. Nördling's formula for new track.	Do.	It is not deemed necessary to lay out a connecting curve on the vertical plane.	Maximum: 1 in 1 000.
Paris-Orleans Railway . .	Cubic parabola.	$y = \frac{x^3}{6lR}$. The lateral displacement to be undergone by the circle towards the inside for inserting the transition is $\frac{l^2}{24R}$.	Do.	No circular connecting curve used in the case under consideration.	1 in 1 000 to 1 in 500. (As far as possible the gradient is never over 1 in 1 000).
Paris-Lyons-Mediterranean Railway.	Cubic parabola.	$y = m x^3$.	Do.	Do.	1 in 333 up to 80 km./h.; 1 in 500 for higher speeds. As far as possible the gradients are reduced to 1 in 666 on main lines with fast trains.
State Railways in Algeria.	Cambier's parabolic connecting curve.	...	—	...	For V < 80 km. h.: 1 in 333 as a maximum. For V ⩾ 80 km./h.: 1 in 500 as a maximum.
Moroccan Railways . . .	Cubic parabola.	Nördling's formula with displacement of the curve or Cambier's method (introduction of a connecting arc).	Polygonal layout (series of inclined planes of equal length).	No fixed rule.	In principle 1 in 500; 1 in 666 in special cases.
ITALY.					
State Railways	Cubic parabola.	$y = \frac{x^3}{C l R}$. id.	In the vertical plane, the transition between the straight sections and the circular curve is laid out linearly.	No fixed rule.	1 in 1 000 for V ⩾ 100 km./h.; 1 in 666 for V = 80 km./h.: 1 in 500 for V < 80 km. h.
LUXEMBURG.					
Prince Henri Railway . .	Cubic parabola.	—	Do.	R = 5 000 m.	According to the formula $1 : n = \frac{1}{10V}$ (max. = $\frac{1}{6V}$), the maximum gradient is $\frac{1}{300}$. When there is not intermediate straight section, the maximum gradient is 1 in 600.
POLAND.					
State Railways	Cubic parabola.	$y = \frac{x^3}{6C}$, or C = l R. For an average speed of: 100 km., C = 60 000; 90 km., C = 45 000; 80 km., C = 32 000; 70 km., C = 24 000; 60 km., C = 18 000.	Do.	The radius is not fixed.	1 in 1 000 to 1 in 400.
RUMANIA.					
State Railways	Cubic parabola.	$x^3 = 24.\ l.\ R.\ V.$	Do.	For gradients with $tan < 0.015$, R = 5 000 m. For $tan > 0.015$, R = 10 000 m.	The gradient being a function of the maximum speed, is equal to h/L (h being the superelevation and L the length of the transition curve).
CZECHOSLOVAKIA.					
State Railways	Cubic parabola.	$y = \frac{x^3}{6C}$.	Do.	R = 5 000 m.	For 60 km./h. . . . . 1 in 300. For 60 to 80 km./h. . . . . 1 in 500. For 80 to 95 km./h. . . . . 1 in 750. For > 95 km./h. . . . . 1 in 1 000.
JUGOSLAVIA.					
State Railways	Cubic parabola.	$y = \frac{x^3}{6C}$.	Do.	R = 5 000 ÷ 15 000 m.	1 in 600, 1 in 500; 1 in 300 as a maximum.

bola $y = \frac{x^5}{C6}$, the other necessary values are calculated :

From the formulae for y' and r_1 we get, when $x = l$

$$\tan \alpha_1 = \frac{l^2}{2C} \quad . \quad . \quad . \quad \text{(IV)}$$

$$= \frac{n^2 h^2_1}{2C}; \; r_1 = \frac{C}{l} \cdot \frac{1}{\cos^3 \alpha_1}$$

deducing C from formula (IV) :

$$C = \frac{l^2}{2 \tan \alpha} \quad . \quad . \quad . \quad . \quad \text{(V)}$$

and substituting :

$$r_1 = \frac{nh_1}{2 \cos^2 \alpha_1 \sin \alpha_1} \quad . \quad . \quad \text{(VI)}$$

The formula (VI) is used for calculating the angle α_1. The other values are calculated from figure V/1 : $b = r_1 \sin \alpha_1$.

According to the equation for the cubic parabola and the formula (V) :

$$b = r_1 \sin \alpha_1 \quad . \quad . \quad . \quad . \quad . \quad \text{(VII)}$$

$$d = \frac{l \tan \alpha_1}{3} = \frac{nh_1 \tan \alpha_1}{3} \quad . \quad . \quad \text{(VIII)}$$

$$p = \frac{l}{3} \tan \alpha_1 - r_1 (1 - \cos \alpha_1). \quad \text{(IX)}$$

$$\lambda = \int_o^{\alpha_1} r dx = \int_o^l \sqrt{dx^2 + dy^2} \; =$$

$$\int_o^l (1 + y'^2)^{\frac{1}{2}} dx = \int_o^l \left(1 + \frac{x^4}{4C^2}\right)^{\frac{1}{2}} dx$$

$$= \left| x \right|_o^l + \frac{1}{8C^2} \left| \frac{x^5}{5} \right|_o^l - \frac{1}{128 C^4} \left| \frac{x^9}{9} \right|_o^l + \ldots$$

$$= l + \frac{l^5}{40 C^2} - \frac{l^9}{1152 C^4} + \ldots$$

$$= nh_1 + \frac{n^5 h_1^5}{40 C^2} - \frac{n^9 h_1^9}{1152 C^4} + \ldots$$

According to the formula (I) the radius of curvature at any point of the transition curve is :

$$r = \frac{C}{x} \left(1 + \frac{x^4}{4C^2}\right)^{3/2}$$

The minimum radius r min of the transition curve is calculated, being given

$$\frac{dr}{dx} = \theta,$$

that is to say

$$\frac{(4C^2 + x^4)^{\frac{1}{2}}}{8C^2 x^4} (5x^4 - 4C^2) = \theta$$

or

$$5x^4 - 4C^2 = \theta$$

The minimum radius is obtained for

$$x = \sqrt[4]{\frac{4C^2}{5}} = 0.946 \sqrt{C} = \xi \quad \text{(X)}$$

The angle α results from the equation

$$\frac{dy}{dx} = \tan \alpha_{max} = \frac{\xi^2}{2C} = \frac{0.946^2}{2}$$

$$r_{min} = \frac{\sqrt{C}}{0.946} \cdot \frac{(4C^2 + 4/5 C^2)^{3/2}}{8C^3} = 1.389 \sqrt{C} \quad \text{(XI)}$$

$$\alpha_{max} = 24^0 \; 05' \; 41''.$$

The sections of the cubic parabola $y = \frac{x^5}{6C}$ can be used for the connections between two consecutive curves of different radii, *owing to the limits imposed by the fact that the radius of the smallest curve must be greater than* $r_{min} = 1.390 \sqrt{C}$ *and that the length of the transition curve should be* $l = 0.946 \sqrt{C}$.

Particular account must be taken of this condition where the length of the transition curve is selected according to the length of the superelevation connection $l = nh$, $l_{max} = 0.946 \sqrt{C}$.

Supposing that the superelevation of the outside rail has been calculated according to the formula $h = \frac{av^2}{gr}$, we get

$$C = \frac{av^2}{g} n,$$

$$x_{max} = l_{max} = 0.946 \sqrt{\frac{av^2}{g} n} = 0.946 \frac{V}{3.6} \sqrt{\frac{1.5}{9.81}} \sqrt{n} = 0.1028 \, V \sqrt{n} \quad . \quad . \quad (XII)$$

For example, when $V = 90$ km. and $n = 750$, $l_{max} = 253$ m., whilst the length of the transition curve is $l = h$, $n = 0.140 \times 750 = 105$ metres (< 253 metres).

When pegging out the transition curve the above exact formulæ are not easily applicable on account of their complication; this is why it is customary to use approximate formulae in which the following approximations are made:

$$\tan \alpha = \frac{l}{2r_1} \quad . \quad . \quad . \quad . \quad (XIII)$$

$$r_1 = \frac{C}{l} \quad . \quad . \quad . \quad . \quad . \quad (XIV)$$

$$C = r_1 l = r_1 nh \quad . \quad . \quad . \quad (XV)$$

$$b = \frac{l}{2} \quad . \quad . \quad . \quad . \quad (XVI)$$

$$b = \frac{l}{2} \quad . \quad . \quad . \quad . \quad . \quad (XVI)$$

The consequence of this is that at the tangent points of the transition curve with the circular curve there are differences in the radius and in the angle of the tangent of the transition curve and of the circular curve. Where these differences reach greater values, it is necessary to rectify the results or else use more accurate fomulæ; for example instead of $C = lr_1$, the more accurate value $C = lr_1 \cos^3 \alpha$ can be used.

When pegging out the transition curve between two curves of radii r_1 and r_2 ($r_2 > r_1$), in practice still other formulæ deduced from the preceding approximate formulæ are used:

$$\lambda = n (h_2 - h_1) = C \frac{r_1 - r_2}{r_1 r_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (XVII)$$

$$\Delta = \frac{1}{24} n^3 (h_2 - h_1)^2 \frac{r_1 - r_2}{r_1 r_2} = \frac{C^2}{24} \left(\frac{r_1 - r_2}{r_1 r_2} \right)^3 \quad . \quad . \quad . \quad . \quad (XVIII)$$

in which λ is the length of the section of the cubic parabola employed as transition curve between the two tangent points A and B, and Δ is the value of the displacement of the curves (see fig. V/3).

The ordinate of the curve at the middle of the transition curve $\omega = \frac{\Delta}{2}$

When pegging out the transition curve between the two curves, widely differing methods may be used. In principle the basis is the use of a polygonal couple (see fig. V/4).

Questions 1 to 6. — In the above investigation we have considered the principle of the transition curve composed of a cubic parabola introduced between the tangent of the circular curve, and the circular curve displaced in the direction of the centre of the curve, as well as the superelevation connection. Most of the railway administrations use the Nördling transition curve. Certain

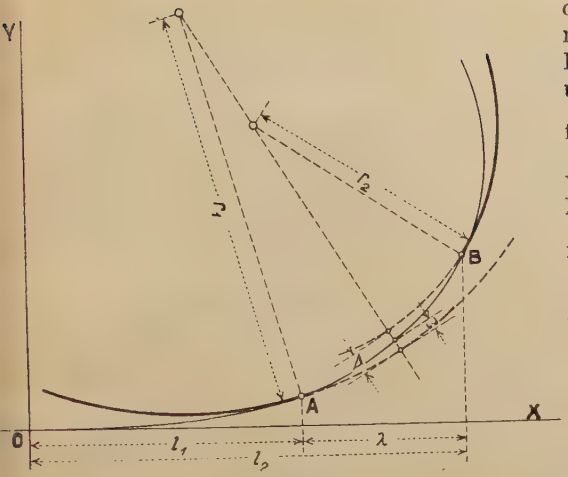


Fig. V/3.

others (see table V) use the Cambier method with a circular curve interposed. For example, the French Nord Railway uses the Cambier layout, the equation for which is : $y = \frac{x^3}{12\,b\,R'}$ when dealing with existing lines (fig. IV/5), and the Nördling layout, the equation of which is $y = \frac{x^3}{12\,b\,R}$ when it is a question of new lines (fig. V/6). The Egyptian State Railways use Trautwine's « Railroad Curves » method.

Question 7. — In principle, all the railway administrations use transition curves of a length equal to that of the superelevation connection. Cases arise

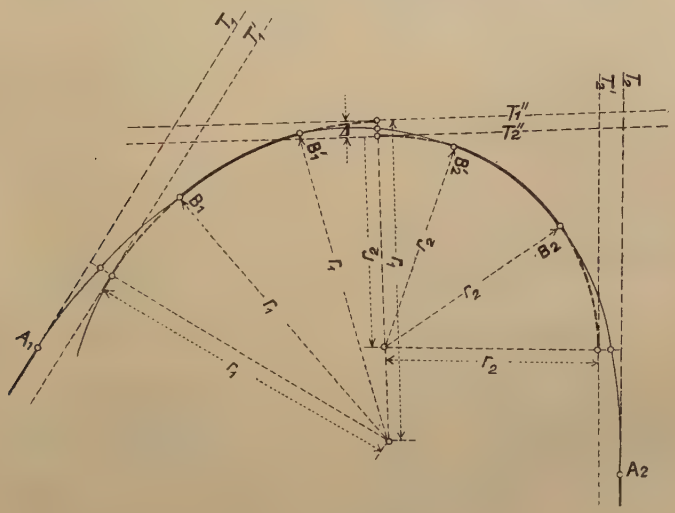


Fig. V/4.

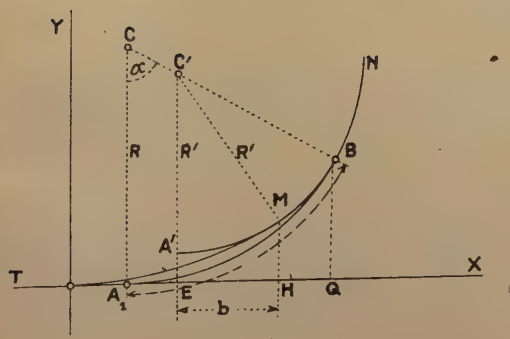


Fig. V/5.

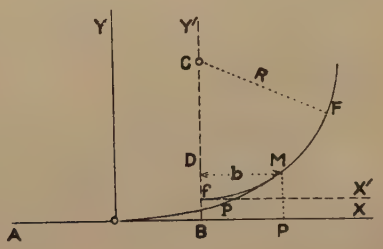


Fig. V/6.

more frequently, however, in which (especially on a short intermediate straight line, between curves in different directions, and also so that the superelevation slope shall not exceed a given value) it is necessary to use a transition curve the length of which may be shorter than the length of the superelevation connection. The superelevation connection can be placed in the ratio to the transition curve given in cases I, II or III in the questionnaire.

VI. — Turnouts and crossings.

QUESTIONS.

1. *What angle of intersection with the stock rail or what angle between the switch tongue and the stock rail* α *and crossing angle* β *(fig. a below) do you use for different turnout radii R in turnouts run over at high speeds :*

a) *on the open road;*
b) *on station arrival lines.*
Please attach a table.

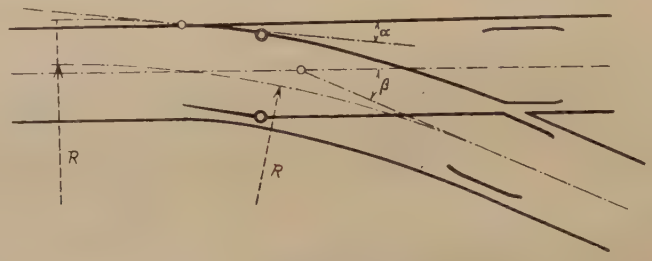


Fig. *a.*

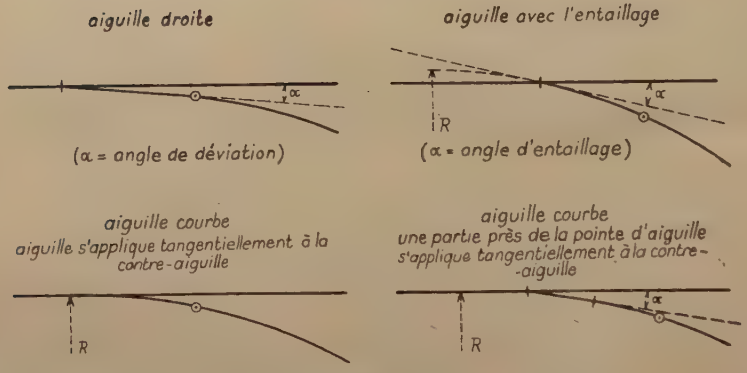


Fig. *b.*

Note. — Aiguille droite = Straight tongue. — Aiguille avec l'entaillage = Tongue intersecting stock rail. — α = Angle de déviation = Angle of deviatino. — α = Angle d'entaillage = Angle of intersection. — Aiguille courbe = Curved tongue. Aiguille... contre-aiguille = Tongue applied tangentially to the stock rail. — Une partie... contre aiguille = The part near the point of blade arranged tangentially to the stock rail.

2. *What design of switch tongue do you use : is it straight or curved ?*

In the second case is the curve arranged tangentially to the running face of the stock rail, or is a part of the switch tongue near the point of blade made straight instead, and what is the angle of divergence, or does the curve

intersect the running plane, and what is the intersection angle (fig. b below)?

3. *How is the heel of the tongue arranged in turnouts for high running speeds ?*

4. *How is the tongue kept in place when subjected to braking action ?*

5. *Do you use tongues housed under the head of the stock rail ?*

6. *Do you use flexible or articulated tongues or both, and according to what principles is one or the other of these types of tongue used ?*

7. *How do you satisfy yourself that when the tongue is moved against the stock rail there is no fear of it not being home : does this safety device depend upon pulling (tongue pulled against the stock rail) or upon pressure (tongue pressed against the stock rail) ?*

8. *Does the radius of curvature through the turnout vary or is it constant ?*

9. *What is the shortest length of straight before and after the theoretical intersection point of the straight crossing ?*

10. *If the curve of the turnout is continued through the crossing, what is the curve radius of the crossing ?*

11. *What is the gauge of curved crossings on the branching off line ?*

12. *What width of flange-way do you allow at the crossing and at the check rail ?*

a) *on the through line,*
b) *on the branch line ?*

13. *Do you take worn tyres into account in the construction of the crossing ?*

14. *Is the wing rail higher than the V piece (nose) of the crossing and by how much (in mm.) ?*

15. *Do you use spring wing rails : are they under spring pressure or are they coupled to the operating gear ?*

16. *Are the crossings in your turnouts for high running speeds built up from rails or of rails and a steel nose, or are they made of cast steel ?*

17. *What minimum lengths of rail or of crossing do you allow in the turnout ?*

18. *How do you prevent rapid wear of the nose of the crossings; what is the maximum wear in mm. allowed of the nose and of the wing rails ?*

19. *Do you use turnouts on the inside and the outside ?*

By turnouts on curves must be understood turnouts laid on a curve on the main line as well as on the branch line.

In the case of turnouts on the inside of curves, the centres of the curves of the main line and of the branch are situated on the same side; in turnouts on the outside of curves, on opposite sides.

20. *In the case of turnouts run onto by fast trains on a curve, are they superelevated, and to what extent relatively to the radius of the curve and to the running speed ?*

21. *What lateral wear in mm. of the rails do you allow in the turnout itself in the case of turnouts on curves ?*

22. *What is the minimum angle, or the minimum angle of the nose of the crossing, of crossings and double slip-roads allowed on the main lines, and under what conditions are they allowed to be used (maximum speed, etc.) ?*

23. *What is the maximum angle of the V piece of crossings and double slip-roads in the main lines ?*

24. *Do you use double slip-roads in which the switches are placed outside the rectangle of the crossing, and what is the radius of these turnouts ?*

25. *Do you use crossings or double slip-points with spring ?*

26. *In the case of lines run over by*

express trains and at the turnouts leading into stations, do you prefer turnouts laid on metal or on wood sleepers ?

27. *What were the deciding reasons for the kind of turnout sleepers selected ?*

28. *What are the maximum speeds allowed over the different types of turnouts on metal or on wood sleepers, in the facing direction or in the trailing direction, on the straight or on curves, in turnouts of different angles, etc. ?*

29. *What are your requirements as regards the construction of the crossing and the layout as a whole, based on your own experience, in order to increase the running speed onto the deviated line ?*

Questions 1 and 2. — See table VI/1. — Practically everywhere the tongues in principle are arranged in such a manner that they touch the stock rail at a given angle of intersection. This angle is in recent turnouts very small (within the limits of about 25′ to 40′).

Tangential contact is not reported by any administration, and this method is no longer considered in turnouts for high running speeds on curves.

Question 3. — The heel of the tongue in switches for high running speeds is built up by an absolutely rigid standard fishing for the flexible tongues and by an assembly with special connecting fish-plates on bearings for non-flexible articulated tongues. The heel of the articulated tongues has a circular pivot, the diameter of the pivot varying considerably. In the construction of the flexible tongue of switches a special rolled section is used, the end of which towards the heel is forged and adapted to the rail section. The articulated tongues can also be run over at the highest speeds owing to the special arrangement of the pivots. The pattern used by the Czechoslovakian State Railways is shown in figure VI/1.

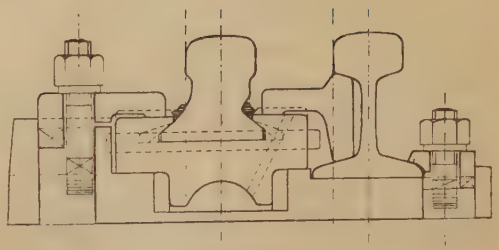


Fig. VI/1.

In this arrangement the tongue heel with the pivot plate is secured by a special locking plate to the bearing carrying the heel.

Question 4. — The tongue should be held in position as far as possible against the braking effects. For example on the French Midi Railway, the flexible tongue is connected on the one hand to the *tongue heel rail* by the rigid fishing (this rail is in its turn connected to the sleepers by a special bearing fastened by a substantial bolt), and on the other hand to the switch sleepers by one or several holding clamps which are bolted to the tongue and coach screwed to the sleepers. The articulated tongue used on the same railway is connected to the tongue heel rail by a fishing allowing the tongue to pivot. A special bearing carries the heel and consists of two stops which fit into recesses in the foot of the tongue so as to prevent any creeping movement. On the Paris-Orleans Railway the heel of the tongue is fixed by a cross stay to the stock rail and to the following rail by means of 4 bolts (fig. VI/2). The French Est Railway

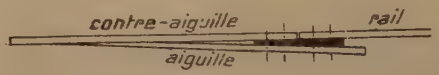


Fig. VI/2.

uses the flexible tongue which, just in front of the fishing, is connected to the stock rail by a stay forming a fixed point, which prevents at the same time

Table VI/1.

ADMINISTRATIONS.	Question 1.				Question 2.				Question 8.	
	Angle of intersection with stock rail		Angle of crossing		The tongue giving the deflection is				Radius of the curve	
					straight	on a curve relative to the switch.	on a wholly tangent curve.	on a partly tangent curve.		
	on the open line.	lines at the entrance to stations.	on the open line.	lines at the entrance to stations.					in the switch.	between the switch and the crossing.
BELGIUM.										
Belgian National Railway Company.		F_7 : 30' F_6 : 30' F_5 : 30' F_3 : 1° 30'		2° 51' 44'' (R = 1 160 m.) 4° 5' (R = 560 m.) 5° 1' 24'' (R = 320 m.) 6° 11' 55'' (R = 180 m.)	—	/	—	—	—	—
EGYPT.										
State Railways	—	—		1 : 8 1 : 10 1 : 12	—	—	—	—	—	—
FRANCE and COLONIES.										
State Railways	25'		3° 26', tan (0.06)		—	/	—	/	—	—
Alsace-Lorraine Railways .	27' 8.15''		4° 05' 8.222'' (1 : 14)			/	—	—		
	40'		5° 42' 38.13'' (1 : 10)			/ curved and deflected towards the inside of the curve.				
	40'		5° 42' 38.13'' (1 : 10)			/				
	33'		5° 42' 38.13'' (1 : 10)			/ symmetrical.				
	33'		5° 42' 38.13'' (1 : 10)			/				
Est Railway	30'		tan (0.06)		—	/	—	—	1 300 m.	1 300 m.
			tan (0.06)		—	/	—	—	900 m.	900 m.
			tan (0.0085)		—	/	—	—	500 m.	500 m.
Midi Railway	25'		2° 58' 36''		/	/	—	/		
	25'		5° 09' 11''							
		25' (1° 19' 45'')		5° 09' 11'', tan (0.09)		α = 25'		d = 1.00 m.		
		25' (1° 19' 45'')		5° 30' tan (0.096)		α = 40'		(for α = 1° 19' 45''		
		25' 40'' (1° 19' 45'')		6° 17' 46'', tan (0.11)		(being designed).		1° 31' 1''		
		25' (1° 19' 45'', 1° 31' 01'')		7° 26' 16'', tan (0.13)						
Nord Railway		51'34''		3° 26', tan (0.06)	flexible tongue 12.00 m. / (symmetrical) +)	—	—	/	+ +) 736 m.	+ 1 329 m.
		51'34''		tan (0.07)	/ (symmetrical) *)	—	—	d = 1.00 m. + +)	**) 736 m.	736 m.
		25'		tan (0.09)	—	/		/	276 m.	*) 945 m.
								d = 4.00 m. **)		502 m.
										320 m.
Paris-Orleans Railway . .	35'	—	tan (0.07)	—	—	α = 35', length of tongue 9.35 m., R = 550.	—	—	Same radius in the switch as between the switch and the crossing. Values were not given.	
	—	1° 32' 38''	—	tan (0.10)	α = 1° 32' 38'',	—				
				tan (0.11)	d = 4.64 m. (length of tongue), R = 245,218					
Paris-Lyons-Mediterranean Railway.		a) 51' 33'' 74		a) 3° 26' 17'' 746 (0.06)	—	—	—	/		
		b) 1° 17' 20'' 17		b) 4° 00' 41'' 48 (0.07)	/	—	—	—		
				5° 09' 30'' 10 (0.09)						
State Railways in Algeria.										
Moroccan Railways . . .										
ITALY.										
State Railways		39' 28'' 342		3° 43' 8'' 378, tan (0.065)	—	/	—	—	—	
LUXEMBURG.										
Prince Henri Railway . .		33'		5° 42' 38'' 13	—	/	—	—	245 m.	245 m.
POLAND.										
State Railways		Less than 1°		(1 : 15)	—	—	—	—	600 m.	600 m.
RUMANIA.										
State Railways		24' 58''		4° 5' 8'' (1 : 14)	—	/	—		500 m.	500 m.
		33'		5° 42' 38'' (1 : 10)	—	/	—		300 m.	300 m.
		40'		4° 51' 26'' (1 :11.8)	—	/	—		245 m.	245 m.
CZECHOSLOVAKIA.										
State Railways		(Syst. A) 49' 41''		6°	—	/ = 49' 41''	—		200 m.	
JUGOSLAVIA.										
State Railways		Xa, 57' 14''		6°	—	—	—	α = 57' 14	150 m.	200 m.

Table VI/2 *(Concluded).*

ADMINISTRATIONS.	Question 23. Maximum angle of the crossing		Question 24.	Question 25.	Question 26.		Question 28.			
							Maximum speed when running over turnouts on sleepers			
							of steel.		of wood	
	Common.	obtuse, of double slip roads.	Do you use double slip roads in which the deflecting devices are located outside the rectangle of the crossing?	Do you use crossings or double slip roads with spring obtuse crossings.	Kind of sleepers adopted for turnouts at the entrance to stations. steel.	wood.	straight line.	curved (branching off) line.	straight line.	curved (branching off) line.
BELGIUM.										
Belgian National Railway Company.	6° 11' 55"	7° 7' 20"	No.	No.	—	/	—	—	F_r : 90 km./h. (laid without superelevation). F_c : 60 km./h. (laid without superelevation).	F_r : 120 km./h. (with superelevation). F_c' : 90 km./h. (without superelevation.
EGYPT.										
State Railways	—	1.8	No.	No.	—	/	—	—	—	—
FRANCE and COLONIES.										
State Railways	7° 30' tan (0.13)	7° 30' tan (0.13)	No.	No.	—	/	—	—	As for Paris-Orleans Ry.	70 km./h. for 3° 26'. 30/15 km./h. for other turnouts.
Alsace-Lorraine Railways .	6° 42' 35.4" (1 in 8.5)		Yes.	No.	/	—	No restriction.	45 km./h.	No restriction.	45 km./h.
Est Railway	8° 30' tan (0.15)	7° 24' tan (0.13)	Yes.	No.	—	/	—	—	Same speed as on the open line, the point being locked.	Either facing or trailing: tan (0.05) (laid without superelevation) 90 km./h. tan (0.05) (laid with superelevation) 100 à 120 km./h. tan (0.06) (laid without superelevation) 80 km./h. tan (0.085) (laid without superelevation) 60 km./h. tan (0.10) (laid without superelevation) 40 km./h. tan (0.11) (laid without superelevation) 40 km./h. tan (0.13) (laid without superelevation) 30 to 40 km./h.
Midi Railway	7° 26' 16"		No.	No.	—	/	—	—	As on the Est Ry.	30 km./h.
Nord Railway	tan (0.13)		No.	No.	—	/	—	—	Do.	Speed restrictions (dependent on the radius of the curves) are shown in table III 1.
Paris-Orleans Railway . .	A = 0.110, and 0.130 (exceptional).		No	No.	—	/	—	—	No restriction.	Generally 30 km./h. for passenger trains and 20 km./h. for goods trains. Exceptionally appliances with long tongues with a curvature of R = 550 m. are run over at a speed of 70 km./h. on the branching off section.
Paris-Lyons-Mediterranean Railway.	tan (0.13)		No.	No.	—	/	—	—	Do.	For (0.06) . . . . . 60 km./h. For (0.07) . . . . . 50 km./h. For (0.09) . . . . . 40 km./h.
State Railways in Algeria.	—	—	—	—						
Moroccan Railways . . .	—	—	—	—	—					
ITALY.										
State Railways	—	—	No.	No.	—	/	—	—	tan (0.065) : no restriction. tan (0.10) : no restriction.	70 km./h.
LUXEMBURG.										
Prince Henri Railway .	1 in 8 (7° 7' 30")	1 in 9 (6° 20' 24")	Yes.	No.	—	/	—	—	60 km./h.	35 km./h.
POLAND.										
State Railways	1 in 10		No.	No.	—				70 km./h., if the point is locked.	40 km./h.
RUMANIA.										
State Railways	5° 42' 38" (1 in 10)		—	No.	—				75 ÷ 90 km./h.	30 km./h.
CZECHOSLOVAKIA.										
State Railways	7°		No.	No.	/	—	100 km./h	30 km./h.	60 km./h.	30 km./h.
JUGOSLAVIA.										
State Railways	6°	10°	Yes.	No.		—	80 km./h	40 km./h.		

any longitudinal movement. The arrangement of the flexible tongue and the stock rail of the Alsace-Lorraine Railways and the Czechoslovakian State Railways, at the heel, is shown in figure VI/3.

The flexible tongue is fastened to the bearing plate which in turn is bolted to the metal sleepers. In order to prevent movement, the foot of the tongue is slotted to take the bolts of the holding clips. The stock rail is secured to the

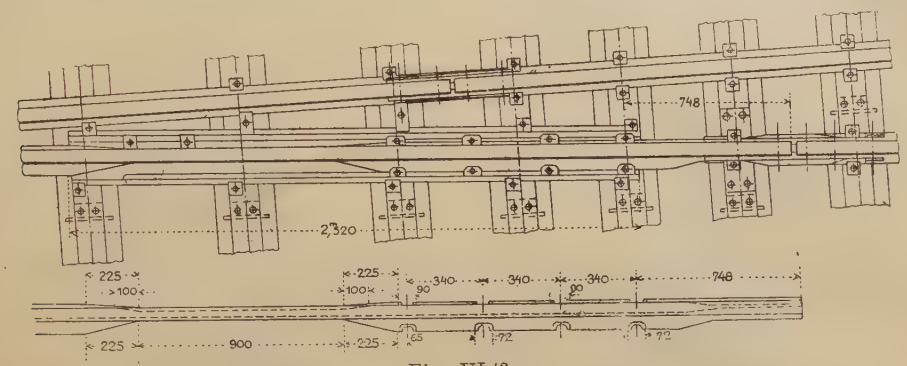


Fig. VI/3.

sleepers and the diameter of the holes for the fish-plate bolts of the joints is 25 mm. (1 inch) [thickness of the bolts 22.5 mm. (57/64 inch)], so that the whole forms a rigid point of support against expansion and against creep.

Question 5. — Most of the administrations who replied use tongues housed under the stock rail (see fig. VI/4).

Fig. VI/4.

On the French Nord Railway the tongues bear laterally on the side of the head of the stock rail. In several types of switches the tongue has in addition a sort of « beak » which engages for a distance of several mm. with the under side of the stock rail head.

Question 6. — As a rule flexible tongues are used on long turnouts for high speeds and articulated tongues for low speeds. Flexible tongues are preferred on main lines with heavy traffic, but there are still in service many turnouts with articulated tongues on the main lines of the great companies. The Paris-Lyons-Mediterranean Railway uses turnouts with flexible tongues only in the case of junctions which have to be taken at high speeds in both directions. The French Nord uses flexible tongues on high-speed lines alone.

Question 7. — As a rule wedging or locking devices are used to make sure the tongue has gone home. These devices are often placed outside the track and bolted to the sleepers. The French Est Railway electrically controls the application of the tongue against the stock rail with an electric indication of the position of the lock or of the wedging device. On the Czechoslovakian State Railways good results have been obtained as regards ensuring the tongue being home by the hook lock shown in

figure VI/5, whereby the tongue is pulled up to the stock rail.

In the case of turnouts run over at high speeds this lock has replaced the old pedal device by means of which the tongue was pushed against the stock rail.

Question 8. — The turnouts used have either a constant radius of curvature from the point of blade to the heel of the crossing, or the radius of curvature of the turnout is different from that of the curvature between the turnout and

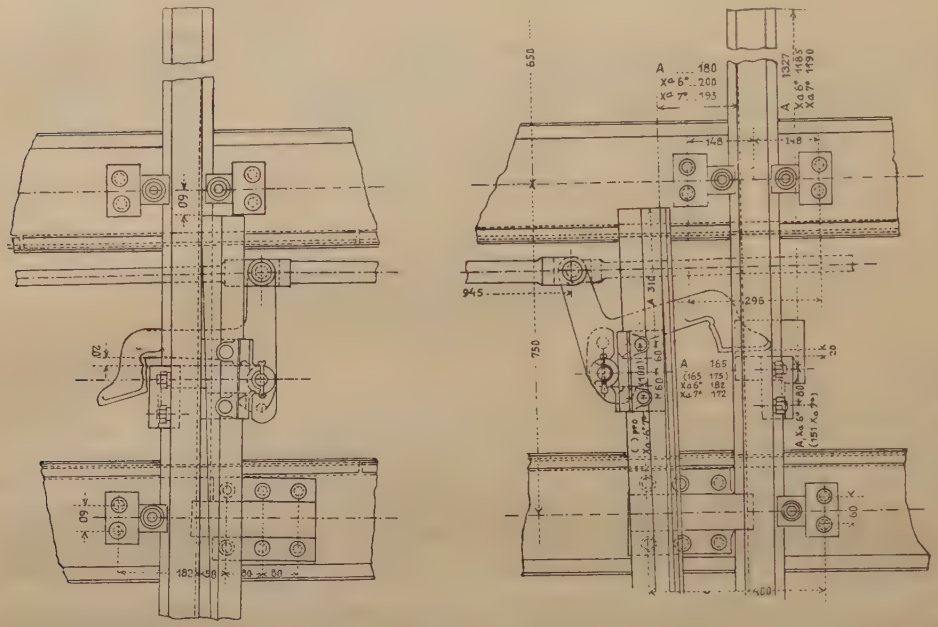


Fig. VI/5.

the crossing. If the radius varies the tangent point of the two radii is generally situated at the heel of the tongue. In most cases the administrations use in turnouts run over by express trains radii of constant value throughout the turnout (see table VI/1).

Questions 9 and 10. — On the French Nord, Midi, Paris-Orleans, Paris-Lyons-Mediterranean, and State Railways, the crossings with rare exceptions are straight. The curve of the turnout is not continued into the crossing. On the other hand the French Est has used since 1911 curved crossings, i. e. crossings in which the curve ends beyond the theoretical intersection point of the crossing. In certain cases the curvature is continued to the end of the heel of the crossing. The radius of curvature in the crossing is the same as the radius of the curved track. The nose of the crossing is straight (see fig. VI/6). The Alsace-Lorraine Railway Company uses for 1 in 10 turnouts, with both roads curved, either similar or contrary flexure curved crossings with a radius of curvature R = 500, or 750 m. (R = 25, or 37.5 chains). (*See replies, table VI/2.*)

Question 11. — The gauge in curved crossings on the French Est Railway is the same as that of the branch line at

the beginning of the crossings, and the same as that of the through line on leaving them.

Question 12. — According to the French Est Railway the width of the flange way between the running rail opposite the crossing and the check rail depends upon the gauge of the track and upon the way the crossing is laid (on straight line or on a line on a curve). This width of flange way is regulated so as to protect effectively the crossing point by the check rail.

Figure VI/6 shows the arrangement of a crossing tan 0.13, in a two-way turnout, the left hand route being on a curve.

In obtuse crossings the length of the gap in the running surface taken between the point rails of the crossing is considerable. In order to reduce this dangerous and unprotected gap in the running surface, the width of the flangeway of the obtuse crossing should be reduced to the minimum by avoiding unnecessary play. Naturally in obtuse crossings and double slip-roads anything

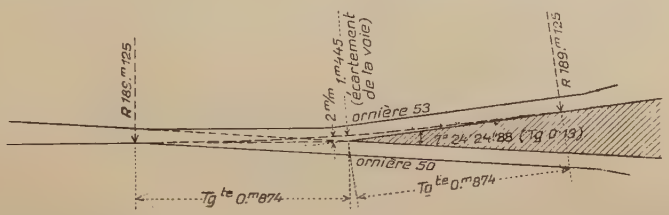


Fig. VI/6.

Notes : Ecartement de la voie = Gauge. — Ornière = Flange way.

which could influence or encourage oscillations about the longitudinal and vertical axes of the vehicle at places situated in front of or on the point rails of the obtuse crossing must be guarded against.

Question 13. — Most of the administrations take into account, as far as possible, worn flanges when getting out the detail drawings, so that every pair of wheels satisfying the limiting prescriptions laid down at Berne can pass through the turnout without incident.

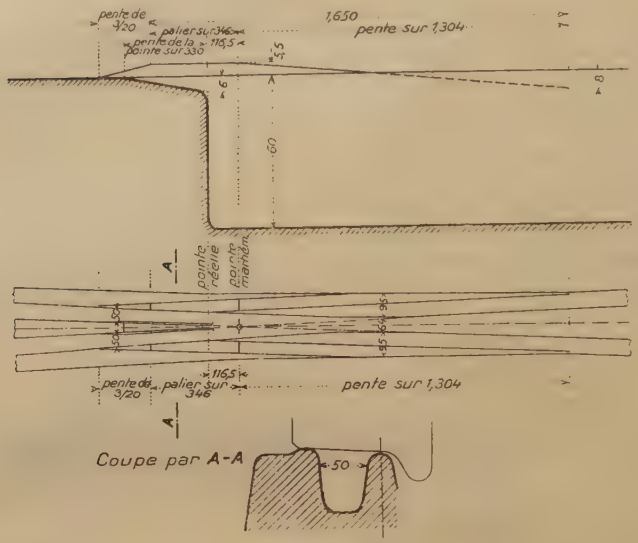
Question 14. — See table VI/2. — At the place at which the point of the nose is strong enough to carry the weight of the wheel, the point rail should be lower than the wing rail, by an amount corresponding to the conical form of the flange in new condition, i. e. by about 5 mm. (13/64 inch). This object is attained either by raising the wing rail relatively to the point rail or by lowering the point rail below the running surface of the wing rail, and frequently by both methods at the same time. Wheels with worn tyres run over the crossing in a different position from that taken up by wheels with new tyres; this is why it is not altogether possible to avoid some of the wheels either dropping or rising when running from the wing rail on to the point rail.

The arrangement in profile of the point rail and of the wing rail for the cast crossing used on the Paris-Lyons-Mediterranean Railway and that used on the Czechoslovakian State Railways is shown in figures VI/7 *a*), *b*) and *c*).

Question 15. — The Paris-Orleans Company has given up the use of this arrangement. The Alsace-Lorraine Railways alone report that they use spring wing rails in two-way turnouts of the standard S 33, 1 in 8 1/2 type. The

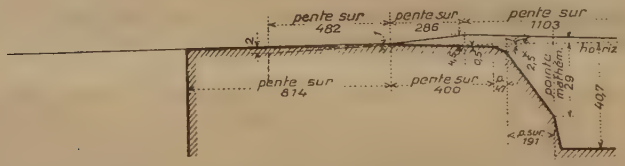
a) France. — Paris-Lyons-Mediterranean Railway.

(LP 0.09 monoblock common crossing with manganese steel nose).



b) Czechoslovakian State Railways.

Xª 1 in 9.51 (6°) monoblock common crossing, with steel nose.



c) Czechoslovakian State Railways.

A 1 in 9.51 (6°) common crossing built up of rails, with steel nose.

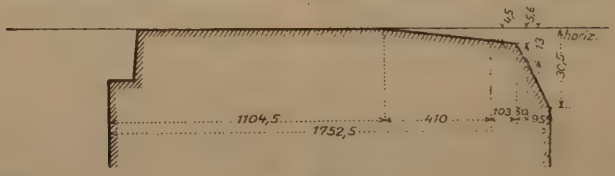


Fig. VI/7.

Explanation of French terms:

Coupe par A-A = Section through A-A. — Palier sur... = Level over a length of... — Pente de... = Slope of... — Pente de la pointe sur... = Slope of point on a length of... — Pente sur... = Slope over a length of... — Pointe mathém. = Point of intersection. — Pointe réelle = Nose of the crossing.

spring push is bolted onto the bearing plate of the V piece.

Question 16. — (See table VI/2). — The French Nord, Est, Paris-Orleans, Paris-Lyons-Mediterranean, and State Railways prefer cast manganese steel crossings in the case of turnouts on their main lines run over at high speeds. The French Est Company uses steel crossings containing 12 to 14 % of manganese; it also has under trial cast nickel chrome steel. In addition to the monoblock crossings various types of crossings built up from rails are frequently used. For example the French Midi Railway uses nothing but crossings built up from standard rails. This railway has since 1926 used a type of strengthened common crossing known as the C crossing, built of Vignole rails weighing 65 kgr. per m. (131 lb. per yard), with 40 mm. (1 9/16 inches) webs, having in the track run over at speed a continuous rail AB (fig. VI/8) in one piece, simply cut away on the top for the passage of the branch line.

In the same way as regards obtuse

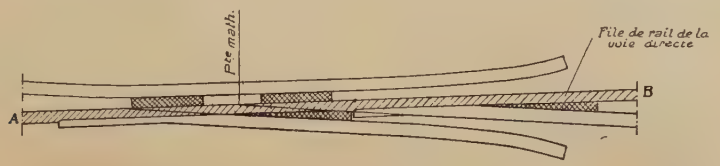


Fig. VI/8.

Note : Pte math. = Intersection point. — File de rail de la voie directe = Line of rails of the main track.

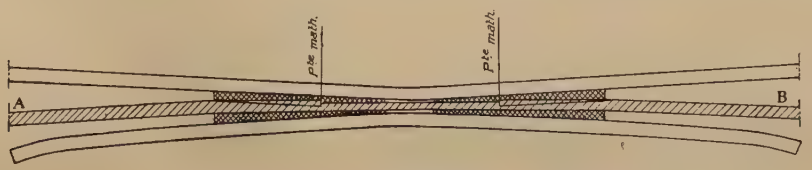


Fig. VI/9.

crossings for through roads the French Midi Railway has in service a type of crossing designed in such a way that the two tongues are arranged in the same rail AB (fig. VI/9).

The rails used are of the ordinary type.

Many administrations use crossings built up of rails with a steel point rail. On the Czechoslovakian State Railways, for example, this type is preferred to the monoblock crossing. The reason for this choice is due to the fact that on this railway metal sleepers are used on turnouts run over at high speeds. The monoblock crossings on metal sleepers have not given good results. On the other hand there is no objection to their use on wood sleepers.

Question 17. — (See table VI/2). — The Czechoslovakian State Railways by welding avoid as much as possible the use of short pieces of rails in turnouts. Welding the rails is also allowed even where it is necessary to use junction fish plates.

Question 18. — As a rule, the rapid wear of the points of the crossings is prevented by using special steel : manganese steel, nickel-chrome steel, heat-treated rails, etc. The other methods consist in protecting the point by the check rail and by lowering the end of

the point rail of the crossing relatively to the wing rails, so that it does not have to stand the wheel blows (see Question 14).

Most of the replies received from the administrations show that the maximum amount of wear allowed at the nose of the crossing or on the wing rail is not laid down (see table VI/1).

Question 19. — Nearly all the administrations use turnouts on inside and outside curves. For example the French Nord Railway uses two radii of the curve on the main lines :

a) 500 m. (25 chains) radius : applicable to turnouts laid in curves up to 625 m. (31 1/4 chains) radius inclusive;

b) 700 m. (35 chains) radius : applicable to turnouts laid in curves of a radius between 625 m. (31 1/4 chains) and 1 000 m. (50 chains) inclusive. Beyond 1 000 m. the turnouts used are of the standard type used on the straight.

The French Est Railway prepares laying plans for turnouts the radius of which varies from 100 to 200 m. (5 to 10 chains for small radii, and 200 to 500 m. (10 to 25 chains) for the large radii.

Question 20. — The main line of a turnout on a curve run over by fast trains is usually superelevated in accordance with the radius and the respective speed as in the case of a curve on the plain running line. Some administrations limit the value of the superelevation in turnouts. This maximum superelevation generally decides the value of the radius calculated relatively to the speed.

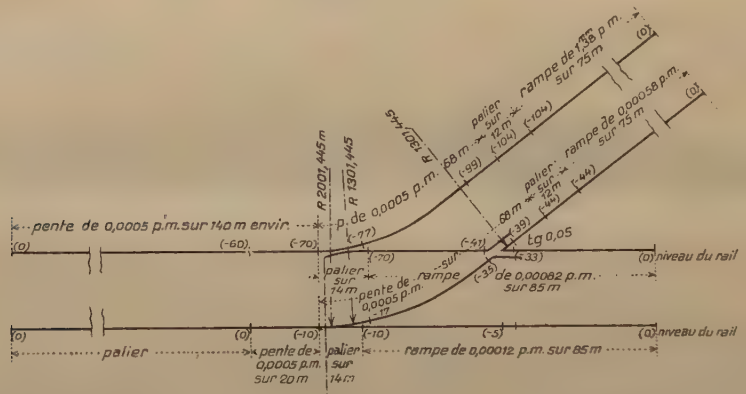


Fig. VI/10.

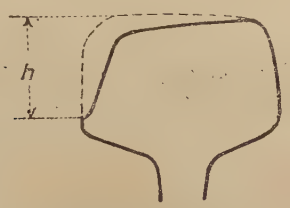
Explanation of French terms :

Niveau du rail = Rail level. — Palier de... = Level for... — Pente de... sur... envir. = Down gradient of... for... about. — Rampe de... = Rising gradient of...

Figure VI/10 shows the lay-out of a tan 0.05 two-way turnout with superelevation, of the French Est Railway, in which the branch line is continued in a straight line after leaving the crossing. In the case of the administrations who do not use turnouts with superelevation or who limit the speed on the turnout curce or place the main direction of the turnout on the straight, as a rule the speed is not limited.

Question 21. — As regards the lateral

wear of the rails in the turnout it is either not limited, or it is the same as on the plain running line. For example, on the Paris-Orleans Railway, the rails are withdrawn from the track when they have reached the limit of vertical wear fixed for each type, distinguishing between lines run over by the expresses, the secondary lines, and the sidings. On the other hand, rails worn laterally are withdrawn from the outer rail of curves when the height *h* of the wear *h* exceeds 30 mm. (1 3/16 inches).



This arrangement has been taken as the result of experience which has shown that for a height of chamfer exceeding 30 mm. certain worn flanges have a tendency to run in the concavity of the chamfer and climb the rail. However stricter limits are now laid down for the stock rails.

For 46-kgr. (92.7 lb. per yard) Vignole rails, the French State Railways allow the following wear :

Wear of the rail head 16 mm. (5/8 inch).
Wear of the foot 2 mm. (5/64 inch).

In the case of lateral wear of the head of the rail these limits are reduced by half the lateral wear measured 15 mm. (19/32 inch.) below the running surface.

Questions 22, 23 and 24. — See table VI/2.

Question 25. — No administration uses spring obtuse crossings.

Questions 26 and 27. — Most of the administrations, and especially the main French Railways (the Alsace-Lorraine Railways excepted) prefer wood sleepers for the turnouts. The arrangement is the same as for sleepers in plain line when it is possible to obtain the kinds of wood required for the track and its equipment. The use of metal sleepers moreover does not permit the use of track circuiting.

The Czechoslovakian State Railways use for the plain line wood sleepers exclusively, although they prefer metal sleepers for turnouts run over at high speeds, seeing that they are easier and more accurate to fit than when the turnouts are laid on wood sleepers.

Question 29. — In order to assure high speed approaching the maximum allowed on the branch line of a turnout, the French Midi Railway has under design a switch with 44 kgr. (88.7 lb. per yard) rails, a tan 0.054 (angle 2°58'36") crossing curve of 1 000 m. (50 chains) radius, a flexible tongue 14 m. (45 ft. 11 in.) long, the whole length being curved with an angle of contact of 0° 25'. The crossing is of the strengthened type C using 68 kgr. (137 lb. per yard) rails. The Paris-Orleans Railway recommends :

For the crossing : The smallest possible angle, but one making it possible to get a satisfactory connection with the appliances which follow it;

For the turnout : the angle of the crossing being given, to select the characteristics so that the angle of deviation is a minimum and the radius a maximum.

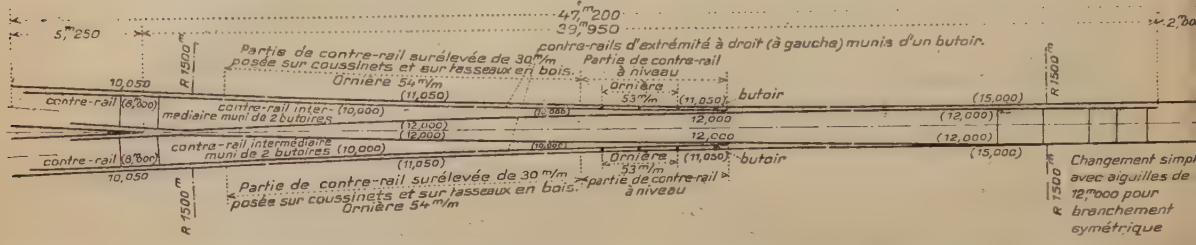
The French State Railways recommend : 1. Smallest possible angle of deviation of the tongue ; 2. Staying of the check rail and of the crossing ; 3. Raising the check rail relatively to the track rail.

The French Nord has commenced the trying out of a type of turnout which will make it possible to take at 120 km. (74.6 miles) per hour the branch lines of junctions. This turnout will include

a flexible tongue giving an angle of only 25' with the stock rail ; the radius of curvature will be about 1 000 m. (50 chains), the curve extending to the crossing under an angle of tan 0.054.

The turnouts of the French Est Railway are built up with the smallest angle of deviation, of 2°51 (tan 0.05) and with a large radius of 1 300 m. (65 chains).

Paris-Lyons-Mediterranean Railway. — Symmetrically-curved turnout ; tan (0.06).


47,m200
39,m950
5,m250
R 1500
Partie de contre-rail surélevée de 30 m/m posée sur coussinets et sur tasseaux en bois.
Ornière 54 m/m
contre-rails d'extrémité à droit (à gauche) munis d'un butoir.
Partie de contre-rail à niveau
Ornière 53 m/m
butoir
10,050
contre-rail (8,700)
contre-rail intermédiaire muni de 2 butoirs (10,000)
(11,050)
(12,000)
12,000
(15,000)
contre-rail intermédiaire muni de 2 butoirs (10,000)
Partie de contre-rail surélevée de 30 m/m posée sur coussinets et sur tasseaux en bois.
Ornière 54 m/m
Changement simple avec aiguilles de 12,m000 pour branchement symétrique

The arrangement with raised check rails between the points and the crossing will only be used in the case in which superelevation corresponding to the authorised speed can not be obtained.

Fig. VI/11.

Explanation of French terms :

Partie de contre-rail surélevée de 30 mm. posée sur coussinets et sur tasseaux en bois = Part of the check rail raised 30 mm. laid on chairs and wood packings. — Partie de contre-rail à niveau = Level part of the check rail. — Contre-rails d'extrémité à droite (à gauche) munis d'un butoir = Right (left) hand check rails fitted with one bearing stud. — Ornière = Flange way. — Contre-rail intermédiaire muni de 2 butoirs = Intermediate check rails fitted with 2 bearing studs. — Changement simple avec aiguilles de 12 m. pour branchement symétrique = Single turnout with 12-m. switch tongues for symmetrical turnouts.

The Paris-Lyons-Mediterranean Company uses methods of construction which can be recommended for turnouts with flexible tongues 12 m. (39 ft. 4 1/2 in.) long and common crossing L. P. A. 0.06. There are 2 types of two-way turnout, LP :

1. Turnout for branch with straight main line ;
2. Symmetrically-curved turnout. *(See fig. VI/11).*

The Czechoslovakian State Railways consider it desirable, from the point of view of the construction of the turnouts, to adopt close spacing of the sleepers under the switch in order to reduce the possible flexion in the vertical direction, as well as a greater number of stops between the flexible tongue and the stock rail. In addition it is necessary to employ a strong lock for the points of the tongue, such as the hook lock.

VII. — Check rails.

QUESTIONS.

1. *Do you use check rails (guiding rails on curves or check rails in turnouts) against which the inside faces of the tyres bear on curves and also at gaps in the running surface on straight lines, solely for motives of security, or are the check rails used in order to diminish the wear of the inside face of the outer rail on curves, i. e. on the ground of economy ?*

2. *What is the width of the normal flange way at the check rails :*

a) *in turnouts and through roads (or diamonds) ;*

b) *on the inside rail of sharp curves of different radii ?*

3. *Is the check rail at gaps in the running surface and at the crossings higher than the running rail, and by how much (in mm.) ?*

4. *What variations ± in mm. are allowed in the width of the flange ways of the check rails ?*

5. *From what radius of curve do you commence to use check rails or guiding rails on the main lines ?*

6. *Does the use of check rails or guiding rails involve any reduction (through increased tractive resistance) or permit any increase (through greater safety against derailment) in the running speed ?*

7. *Do you use check rails or a guiding rail on down gradients and on the level only, or also on rising gradients ?*

8. *Are guiding rails used along the full length of the transition curve, or in the absence of a transition curve, along the straight and to what length ?*

9. *What advantages (for example, greater safety against derailment, reduction of side wear of the outer rail) and what disadvantages (for example, greater train frictional resistance, greater cost of installation) have been found when check rails are used in the main lines ?*

10. *Do you also use check or guard rails as a means of protection, i. e. rails on the inside of a curve with which the tyres come into contact only in case of derailment, the curvature being left out of consideration (for example, on long and high bridges with superelevated lines, on bridges with sharp curves, on high retaining walls, on level crossings with heavy road traffic, etc.) ?*

11. *What is the width of the standard flange way in such guard rails ?*

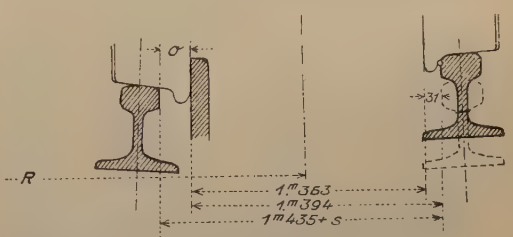
12. *Is the guard rail higher than the rail and how much, in mm. ?*

13. *Have you records of cases in which accidents, the consequences of which might have been serious, have been prevented by the guard rail, the use of wich has thereby been justified ?*

Question 1. — All administrations use check rails in turnouts through roads and slip-roads, in order to protect the common or obtuse crossings at the gaps in the running surface. Check rails on curves, however, are only used on some railways. The reason for using check rails is in the first place safety ; but in certain cases they are also laid on the running lines to prevent too rapid side wear of the outer rail.

Question 2. — *a*) The width of the flange ways in turnouts, through roads and slip-roads, as a rule is so arranged that when the tyre is against the check rail there still remains a few millimetres play between the flange of the other tyre and the point of the crossing, the flange being supposed new.

b) As regards the width of the flangeway on the inside line of rail on small-radius curves, it is fixed in such a way that the wheels can use the whole width of the track, i. e. that the tyre of the wheel on the inside rail being against the check rail, the flange of the other wheel, supposed to be new, just comes into contact with the rail on the outer line. Figure VII/1 shows the method of



Radius of curve R.
Standard gauge of 1.435 m. (4 ft. 8 1/2 in.).
Gauge widening s.
Thickness of new wheel flange 0.031 m.
σ + 1.363 ÷ 0.031 = 1.435 + s.
σ = 0.041 + s.

Fig. VII/1.

arriving at the width of the flange way between the inner rail and the check rail.

For s the value taken should be in accordance with the formulæ VII or VIII of Chapter II. For example, when R = 180 (9 chains) and d (distance between wheels) = 4 m. (13 ft. 1 1/2 in.), s = 28 mm. (1 7/64 in.) and o = 69 mm. (2 23/32 inch.).

Question 3. — The check rail in through roads and in slip-roads (obtuse crossings) is raised on all railways. Some administrations also use raised check rails for protecting the points of common crossings in turnouts.

In slip-roads the rails converge at an obtuse angle at the same crossings. It is not possible to place the check rail in line with the gap so that the wheel can be protected and guided over the whole length of the interruption of the running surface. The smaller the angle of the crossing, the longer the part not protected. For example, if an obtuse crossing, hangle 6°, with the check rail raised h = 38 mm. (1 1/2 inch.), with a wheel radius r = 0.5 m. (1 ft. 11/16 in.), the length of the gap in the running surface between the point at which the flange [in new condition 25 mm. (63/64 inch) high], when approaching the point of the crossing leaves the check rail point 1 to the position of contact with the point of the point-rail 2 (see fig. VII/2),

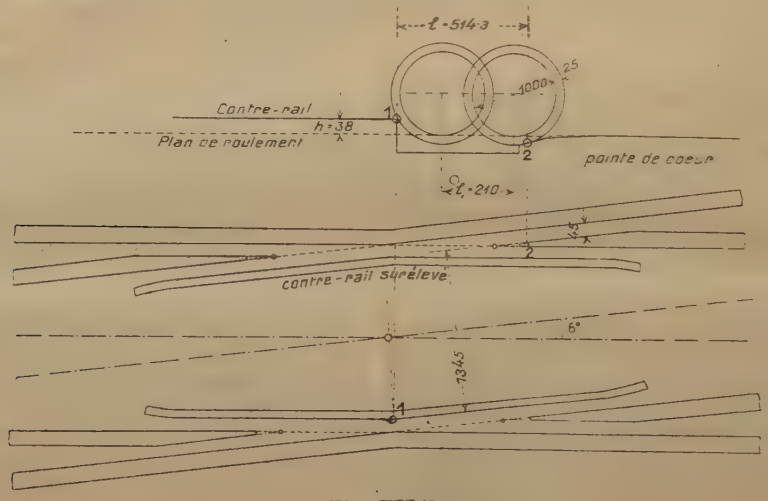


Fig. VII/2.

Explanation of French terms:

Contre-rail = Check rail. — Plan de roulement = Running surface. — Pointe de cœur = Nose of crossing. Contre-rail surélevé = Raised check rail.

is l = 0.514 m. (1 ft. 8 /16 in.) from which the non-protected part is found to be l_1 = 0.210 m. (8 1/4 inches).

The length of the unprotected gap can be reduced by raising the check rail. The amount it can be raised is however limited. For example on the Czechoslovakian State Railways there is a space of 50 mm. (1 31/32 inches) above the running surface of the rail, a measurement limited by the clearance gauge.

The amount h the check rail can be raised on the Czechoslovakian State Railways in the case of the obtuse crossings

of slip roads of recent types is 38 mm. (1 1/2 inch.). The maximum wear of the wing rail [12 mm. (15/32 inch.)] is taken into account at the same time, so that in all for a rail worn down 12 mm., there is an available height of 38 + 12 = 50 mm. (1 31/32 inches) in the limit allowed by the clearance gauge. On the old type of obtuse crossing in which the check rail when new was raised 60 mm. (2 23/64 inches) above the wing rail, the spring buckles on a locomotive on which when new the spring buckles were 104 mm. (4 5/64 inches) above the running surface came into contact with the check rail. With the minimum tyre thickness of 40 mm. (1 9/16 inches), 5 mm. (13/64 inch) wear in the axle boxes and 12 mm. (15/32) wear of the wing rail, the height *h* became reduced from 104 mm. (4 5/64) to 47 mm. (1 27/32 inches), with the result that the buckles of the springs and the check rail fouled by 60-47 = 13 mm. (33/64 inch).

Question 4. — The Alsace-Lorraine Railways arrange the check rails on the crossings with standard S 12 and S 33 rails, so that, by removing a packing 4 mm. (5/32 inch) thick arranged between the check rail and the bearing studs, the worn check rail can be restored to the normal distance of 41 mm. (1 39/64 inch) from the running rail. When the wear of the check rail reaches 4 mm. (5/32 inch) it is only necessary to remove the packing and reverse the clip.

Question 5. — The Alsace Lorraine Railways use check rails on curves of a radius R = 500 m. (25 chains). The check rail used in special cases on small radius curves on the Paris-Lyons-Mediterranean Railway is generally raised 30 mm. (1 3/16 inch) above the running surface. On other railways the check rail is only used in exceptional cases and there is no definite regulation on the subject.

Questions 6 to 9. — The replies from the administrations using check rails on curves show that this arrangement has an insignificant effect on increasing the tractive resistance. On the other hand, the check rails offer much greater safety against derailment. The question of up or down gradient has nothing to do with the use of check rails. The check rails are only used on curves of small radius. On the Alsace-Lorraine Railways, the check rail usually is continued to the middle of the transition curve. The use of check rails has the advantage of reducing the wear on the inside face of the outer rail on the curve. Against this, disadvantages are the costs of installation and maintenance.

Questions 10 to 13. — The French Est Railway lays guard rails on certain long and high metal bridges, along retaining walls, and parallel to the piers of structures over the track. These guard rails are generally placed outside the track. The guard rails at level crossings are placed inside the track, and are bent at their ends so as to increase the flange way to about 110 mm. (4 11/32 inches) on entering and leaving them, to prevent the flanges striking. The Alsace-Lorraine Railways vary the width of the flange way in accordance with the radius of the curve.

The Czechoslovakian State Railways prefer to use long timbers at level crossings rather than metal check rails.

Guard rails on metal bridges are made either from old scrap rails or special section rolled bars or timbers sometimes flitched with angles.

Most administrations consider guard rails should be used on long metal bridges. The guard rail on bridges is not raised in every case. The replies received show the administrations have not had to report any cases in which accidents which might have had serious consequences have been prevented by

guard rails. The Rumanian and Egyptian State Railways alone mention in a general way that accidents have been prevented by the use of guard rails on metal bridges. According to the French Est Railway, no case is known in which a serious accident would have been avoided solely by guard rails being used ; but as their use is very limited and as their first cost and cost of maintenance are small, this Company considers that such a safety measure is well justified.

CONCLUSIONS.

I. — Strength of the track.

The reciprocal reactions between the vehicle and the track are not sufficiently well known for it being possible to calculate with precision the dimensions of the different parts of the track. Calculations are, however, useful as they make it possible to form a judgment on and make a comparison between the maximum wheel loads and the maximum train speeds. The results of these calculations should be supported by experience.

The need for a more complete knowledge of the ratios and the values of the forces acting on the track is felt both as regards the financial aspect and the technical. It is desirable that attention should be given especially to vibratory phenomena, by carrying out systematic tests on a much greater scale, by means of suitable apparatus. In view of the magnitude of these tests and observations it is desirable that several railway administrations should co-operate in making them.

II. — Gauge widening on curves.

The gauge widening on curves depends generally upon the radius of the curve and the wheel base of the vehicles. As a rule, the amount should be large enough for the rigid wheel base vehicles to pass freely round the curve. A greater gauge widening enables the vehicle to place itself obliquely relatively to the outer rail, and this increases the rolling resistance and the lateral wear of the outer rail. A greater gauge widening moreover assists the lateral transverse movements as well as the rotary movements about the vertical axis of the vehicle, and thereby increases the dynamic effects of the transverse forces.

It is desirable that the maximum wheel base of the vehicles should be decided according to the radius of the smallest curve and the gauge widening.

III. — Radius of curves.

1. The maximum speed allowed on curves depends upon the radius thereof, and upon the superelevation of the outer rail.

2. On main lines over which express trains run the curves should have large radii so that the trains can be run as far as possible without any reduction in the maximum speed allowed.

3. The use of intermediate straight sections of minimum length between the curves depends upon the value of the superelevation gradient. If this slope is $\frac{1}{n}$ with $n \geqslant 8$ V (V = maximum speed in km./h.) it is sufficient to provide :

a) between the ends of the superelevation connections of curves in the same direction, an intermediate straight section of a least 30 m. (98 ft. 6 in.) length. In the case in which $n \geqslant 10$ V, this intermediate straight section can be reduced to 15 m. (49 ft. 3 in.).

b) between the ends of the superelevation connections of curves in opposite directions, an intermediate straight section of at least 20 m. (65 ft. 7 in.) length. In the case when $n \geqslant 10$ V, this intermediate straight section can be omitted and an inflected connection be put in between one curve and the other.

When $n < 8$ V it is desirable to ex-

tend the minimum intermediate straight section proportionally.

When it is not possible to insert an intermediate straight section of minimum length between curves in the same direction, it is desirable to replace this straight section by a curve.

On compound curves, when the difference of superelevation exceeds 10 mm. (3/8 inch), a transition curve should be inserted between the different curves of different radii.

In order to counteract the disturbing influences due to the oscillations of the vehicles about the longitudinal axis on short curves, the length of the true curve with full superelevation of the outer rail between the superelevation connections, should be at least equal in length to the length of the superelevation connection.

5. On double track lines when one line has to be slewed to increase the distance between the lines, sufficiently large radii should be used, so that the outer rail need not be superelevated.

6. When the superelevation connection is on a gradient of 1 in n, with $n \geqslant 8$ V, it is desirable to place an intermediate straight section at least 20 m. (65 ft. 7 in.) long between a facing point on the straight and the beginning of the transition curve of a curve on the running line. When the gradient is steeper, the length of the intermediate straight section should be increased proportionally.

When the switch is run over in the trailing direction, the intermediate vation is at least 10 mm. (3/8 inch).

As regards the minimum length of the intermediate straight section between the curve before or after the turnout and the turnout curve, the same principle as that under (3), is applied when the turnout curve is superelevated.

7. In order to correct the layout and the gradients of the main lines, reference marks for verifying the position of the track, as well as for correcting the curves, by the method of arcs of circles should be used. Such measurements are advantageous from the financial and technical aspects.

IV. — Superelevation.

1. The influence of the centrifugal force on curves on the vehicles is counteracted by the superelevation of the outer rail. A lower superelevation than that obtained from the theoretical formula $h = 118 \frac{V^2}{R}$, in which V is the maximum allowed speed in km./h., can be allowed with safety as regards the traffic.

When most of the trains over a line are run at lower speeds a lower speed according to local experience may be taken, instead of the maximum speed V of the fastest trains.

2. The full superelevation should be provided at the beginning of a curve.

3. When a straight line at least 30 m. (98 ft. 6 in.) long cannot be laid between the theoretical ends of the superelevation connections of two neighbouring curves in the same direction, the superelevation should not be less than one half to one third of the corresponding value for the largest radius.

If the curves are so close that the ends of their superelevation connections touch or overlap, the superelevation in the connection between one curve and the other should be made by a uniform linear slope between the extreme ends of the curves.

4. In the case of a compound curve, it is desirable to make the superelevation connection on the lengths of the intermediate transition curves.

When there are no transition curves between curves of different radii, for example in cases in which the dfference of the superelevation of two neighbour-

ing curves is very small [10 mm. (3/8 inch.) at most], it is to be recommended that the superelevation connection should be laid in on the curve of the larger radius.

5. The variations in the standard superelevation should not exceed ± 10 mm. (3/8 inch.).

V. — Transition curves.

1. All lines run over at high speeds should have transition curves between the straight sections and the curves. In the same way on compound curves, there should be intermediate transition curves between the curves of different radii, when the difference in superelevation is at least 10 mm. (3/8 inch).

2. When cubic parabolas are used for transition curves, they can only be used within certain limits, i. e. so long as the radius of the curve is greater than the minimum radius of the cubic parabola, and the length of the transition curve is less than the maximum abscissa of the cubic parabola. In these cases the cubic parabola perfectly satisfies practical requirements.

3. The length of the transition curve and that of the superelevation connection should as a general rule equal one another. When this is not possible and the length of the transition curve has to be smaller for various local reasons, the superelevation on the connection should be so arranged that at the beginning of the curve the superelevation should as far as possible be the full amount.

4. The linear superelevation connection is quite satisfactory. The graded connections at the beginning and at the end of the transition curve are not indispensable, when the slope of the superelevation connection is moderate, i. e. at least $n \geqslant 8$ V.

VI. — Turnouts and crossovers.

1. When the turnout is run over at high speeds onto the branch, it is desirable to use as large as possible a radius for the turnout curve and to make provision if need be for the superelevation of the outer rail over the whole of the turnout curve ; provision should also be made for a closer sleeper spacing and possibly the use of sole plates, a sufficient number of bearing studs, suitable methods for making sure the switch tongues are home, such as for example the hook lock, and in addition a suitable strength of the tongue and of the stock rail to stand the longitudinal forces due to braking. It is an advantage for the point to be housed under the head of the stock rail.

2. The switch curve can be continued in the crossing and even beyond it. When the curve extends past the crossing, the flange way at the crossing is enlarged in correspondence with the curve. The use of curved crossings has not become general, and for this reason the desirability of this arrangement should be investigated.

3. The point of the crossing is effectively protected by moderately raising the wing rail in the case of monoblock crossings, or by lowering the point in the case of built up crossings. The amount of this difference of level, a result of the conical tread of the tyre, should be based on the average tyre wear.

Spring wing rails have not been widely used so far.

4. Monoblock crossings in special steels are used especially on wood sleepers. The point of crossings built up from rails is made of special steel. These two patterns of crossing can be used for high speeds.

5. When the crossing angle is too small, the whole of the gap in the running surface cannot be protected by

means of check rails. Crossing angles not less than 1 in 10 should be used on slip-points on lines run over at high speeds.

VII. — Check rails.

1. A special rolled section instead of a rail section should be used for the check rail.

In the case of crossings and slip-points, raised check rails should be used, as this method makes it possible to reduce the length of the gap in the running surface.

In the case of single crossings the check rail should also be raised.

2. Check rails on the inside rails on curves are only used on curves of small radius. The width of the flange way depends upon the radius of the curve and consequently upon the gauge widening. It is unusual for the flanges of the two wheels of the same pair to bear simultaneously on the check rail and on the outside rail. The check rail when placed at a suitable distance from the inside rail protects the outer rail against premature lateral wear, without however in any way making it possible to increase the allowable speed on the curves. When the use of check rails on curves cannot be given up, special rolled sections should be used.

3. The object of fitting check rails at level crossings is to make it easier to maintain the flange way. In place of check rails, longitudinal timbers are used with advantage.

4. The use of guard rails of special rolled sections, or timbers on structures, is limited, as a general rule, to long metal bridges, or to special and exceptional cases. The flange way should be at least sufficiently wide to take the whole of the tyre in case of derailment.

NEW BOOKS AND PUBLICATIONS.

[313 : 385 (.44)]

GODFERNAUX (R.), Engineer, Member of the Committee for Public Works in the Colonies, France. — **Les Grands Réseaux de Chemins de fer français, année 1931**. (*The French Main Line Companies, year 1931*). — A pocket book (6 3/4 × 4 1/2 inches) of 40 pages. — 1932, Paris. Dunod, 92, rue Bonaparte. [Price : 6 fr. (French currency)].

In this annual review the author has brought together the statistical tables relating to the main line French Railways (Nord, Est, Orleans, Paris-Lyons-Mediterranean, Midi, State, Alsace-Lorraine) : length of line, staff; stock and shares, capital cost, operating results and financial results; profit gained by the State from the operation of the railway systems; analyses of the traffic, rolling stock, and the mileage run.

Compared with the previous year, the year 1931 shows a net operating profit which has fallen from 1 800 millions to 700 millions, in spite of a reduction in expenditure of 300 millions. The receipts have fallen by 1 400 millions. Taking into account the various charges, the financial situation of this year ends with a deficit of 2 569 millions, plus 500 millions representing the costs of repaying to the State deficits of the years 1921 to 1925.

The author gives a brief and sound commentary on this situation. He reminds us first of all of the main features of the Agreement of 1921 which set up some financial union between the main line Companies, and he explains the working of the « Common fund ». Finally he reviews the causes of the deficit and the proposed remedies. Among these will be noticed the new operating programme of the railways which has been approved by the Higher Railway Council, and from which substantial economies are expected together with an increase of receipts owing to the new facilities offered to the public.

In this interesting pamphlet will also be found the principal happenings of the year, a comparison between the rates and taxes in 1914 and 1931, the principal foreign connections, long distance runs without stop, and the high speeds of the trains, the principal runs of the international expresses, with their distances, noted on diagrams in kilometres and in hours.

E. M.